The Development of Tools and Guidelines for Surfing Resource Management

A thesis

submitted in fulfilment

of the requirements for the degree

of

Doctor of Philosophy in Earth Sciences

at

The University of Waikato

by

EDWARD ANTHONY ATKIN

2023

Abstract

Surfing is a mainstream pastime and competitive sport in many countries and provides a full range of economic, social, physical, and mental health benefits. Maintaining the integrity of surf breaks has proven to be a challenge, with a litany of degraded or destroyed surfing locations worldwide. This is attributed to a deficiency in expertise and experience in implementing surf science and management within governing authorities, associated consultants, or stakeholder groups; combined with a lack of value recognition and identification. This work considers how surf breaks as coastal resources could be better managed.

A literature review of technical reports, published articles, statutory instruments, evidence, and consents, along with interactive stakeholder workshops and surveys to identify key considerations, are combined with complex numerical modelling and machine learning methods to develop tools for effective surf break management.

In Aotearoa New Zealand, a surf break is described in policy as having various geophysical components in the vicinity of locations where surfing takes place and the areas offshore. Given the wide range of benefits associated with surfing, and the complexities of managing a natural resource, albeit in some cases anthropologically modified, the term 'surfing resource' was established and defined as a major outcome of this work and as a step in the process of developing a set of Management Guidelines for Surfing Resources (the Guidelines). The Guidelines, which are a world first, consider what aspects of the environment are the most important to surfing resources management, provide direction, as implementable steps, to authorities and proponents of activities in the coastal environment that can impact surfing resources, and include identification and monitoring strategies as well as a novel risk assessment framework which is underpinned by a surf break's sensitivity as a function of geomorphological composition.

The Guidelines are supported by research streams that required field data collection and monitoring system development, numerical modelling, and machine learning to improve our understanding of surf break functionality and/or better our management strategies. This work emphasises the role of bathymetric features outside the surf zone that contribute to surfing wave quality, and the value of establishing swell corridors for management purposes. An automated system has been developed to monitor the key surfing wave quality indicator of peel angle through both space and time.

Effective surfing resource management requires a holistic, inclusive, case-by-case approach, that may require cultural, social and geophysical assessment, which is best implemented proactively with the identification of surfing resources and the establishment of environmental baselines.

Acknowledgements

Many thanks to all those that participated in workshops, not just as part of the overarching research project but other events at which I have contributed to organising. In all aspects, the objective of enhancing our collective understanding of surfing resources, with the aim of improving management was achieved. Many thanks to the hosts of the camera sites associated with this research, and all those that have allowed access for data collection.

To my collaborators on the overarching research project, Professor Karin Bryan, Dr Terry Hume, Dr Shaw Mead and Dr Jordan Waiti, our collective efforts pulled off something unique. Thank you. My other collaborators, Dougal Greer, Jai Davies-Campbell, Rhys McIntosh, Dr Shane Orchard, Dr Dan Reineman, Attorney Jesse Reiblich and Dr David Revel, it was a privilege working with you, thanks for brainstorming and looking forward to future projects together. Thanks as well to all those who listened and provided feedback on the long and winding road.

Dr Shaw Mead gets a special mention as an undergraduate's inspiration, through to mentor, business partner, supervisor, and buddy. Thank you for the opportunities and guidance.

Thanks to the American Shore and Beach Preservation Association, Australasian Coasts and Ports, Coastal Education and Research Foundation, Inc., and Coastal Engineering Research Council of Coasts, Oceans, Ports, and Rivers Institute for agreement to the reproduction of publications for the purpose of this thesis.

Patience is something I am very grateful for. In this regard, many thanks to Professor Karin Bryan, my chief supervisor. Beware the part-timer with a young family, starting a new business, and a penchant for volunteer emergency services. None have been more patient though than my family. Ruan, June, Amber and Ash, my apologies for all the late nights, missed events and being absent on the weekend. The drawn-out nature of this doctorate is as much a product of us having fun together along the way as it has been the sizable workload, the former of which we now have more time for. Thank you for your patience and support.

Contents

Tables

1 Introduction

Surfing is a water sport where a participant is intentionally moved by a wave. The act of surfing spans a broad range of crafts (e.g., surfboards, bodyboards, stand-up paddleboards, kayaks etc.,) and skill levels across different breaking wave types. Those learning to surf often utilise the bore of whitewater created during wave breaking, whereby the rider is projected in the same direction as wave propagation. As a surfer's skill level increases, they begin to ride across the unbroken wave face, and for this to happen the waves must 'peel'. A peeling wave refers to the breaking part of the wave, or pocket. The surfer must move along the peeling wave at a rate that is equal to or greater than the rate of breaking.

The benefits associated with surfing are broad but include physiological, social, mental health and wellbeing, educational, psychosocial development and economic (Armitano *et al.*, 2015; Caddick *et al.*, 2015; Clapham *et al.*, 2014; Hignett *et al.*, 2018; Lazarow, 2007; Roman *et al.*, 2022; Wheaton *et al.*, 2017). The most tangible benefits for those that do not participate in surfing, and perhaps those that resonate best with decision and policy makers, are the economic benefits. The discovery of new surf breaks has shown a correlation with economic growth, where surf breaks were once valued at an estimated USD 50 billion globally (McGregor and Wills, 2016; 2017), and annual surf tourism expenditure was estimated up to USD 64.9 billion (Mach and Ponting, 2021). Studies have explored the relationship between house and rental prices and proximity to surf breaks, with higher-quality surfing locations increasing property prices (McGregor and Wills, 2016; 2017; Neubauer, 2006; Scorse *et al.*, 2015; Scorse and Hodges, 2017). Using surfing as a marketing tool in everything from credit cards to watches and motor vehicles is a testament to the popularity of the sport. A study of 'Surfonomics' (Nelsen *et al.*, 2007) attempts to capture the non-market values and wider economic impacts of surf breaks (Scorse and Hodges, 2017). The annual economic contribution from recreational surfers associated with the surf breaks of Huanchaco (Peru), Mundaka (Spain), Pichilemu (Chile), Mavericks (USA) and Uluwatu (Indonesia) are USD 1.7 M, 1–4.5 M, 2–8 M, 24 M and 35 M, respectively (Gilje, 2018).

There are more than a million kilometres of coastline worldwide, much of which is sufficiently exposed to receive waves from distal or proximal sources. However, the presence of waves does not necessarily mean there are surfing opportunities. Surf breaks are distinct and discrete geomorphological features of a coastline that can be dependent on specific wave heights, periods and direction; they may require waves from rare events such as tropical cyclones, and at any time, these waves may need to combine with specific tidal heights and wind directions to be surfable. Surf breaks are extremely dynamic, and their prevalence is just as much determined by the configuration of the seabed as it is by incident wave conditions.

Activities in and around the coastal marine environment have been shown to impact surfing amenity value, whether it be restriction of access, water quality issues, loss of wave quality or destruction of the surf break (Hewett, 2011; Liria *et al.*, 2009; Nelsen *et al.*, 2013; Mead and Atkin, 2019; Scarfe *et al.*, 2009a, 2009b;) and Aotearoa New Zealand (ANZ[1]) is no exception. Negative impacts on surfing amenity can impact tourism, the community and local businesses (Lazarow *et al.*, 2008). Common themes in cases of mismanagement include the recognition of values associated with a surf break, a lack of baseline data and scientific understanding, and a lack of procedures and methods to follow (Skellern *et al.*, 2013). Real, perceived or potential impacts resulting from this lack of understanding have led to discord between stakeholders and developers.

In 2010 a revised version of the New Zealand Coastal Policy Statement (NZCPS) was published. The NZCPS guides regional, district, city and local councils in their day-to-day management of the coastal environment. The NZCPS is mandatory under the Resource Management Act 1991 (RMA). The 2010 revision included *Policy 16: Surf Breaks of National Significance*, and other policies with references to the management of surf breaks. Since 2010, conflicts concerning activities that affect surf breaks have continued in ANZ despite implementation of mandatory policies regarding surf break protection. Personal experience, as a technical advisor to a number of groups focused on the conservation of surf breaks, has provided insight into conflicts that repeatedly expose shortcomings in management strategies and highlighted the need for establishing baseline datasets, methods for understanding the functionality of surf breaks, and consistency in how measures and potential impacts are interpreted. Compliance with environmental legislation comes at a cost, a cost that is viewed as an impediment to development and economic growth; however, the cost can inflate with discord between experts.

This research aims to improve the scientific foundations that contribute to management practice and planning strategies around surf breaks. This is achieved through a combination of detailed literature reviews, stakeholder workshops to elicit engagement from local expert knowledge holders, examination of specific sites in terms of geomorphology, surfing wave quality and bathymetric configuration, the establishment of surfing break monitoring systems, data analysis and the development of new techniques. The learnings are amalgamated into the Management Guidelines for Surfing Resources (Atkin *et al.*, 2019; the Guidelines henceforth; Appendix A), and supported by tools to help monitor, manage, and better

---

[1] Aotearoa New Zealand is a contested name. It is widely used by central government, was endorsed by the former prime minister (Jacinda Ardern) and used in contemporary publications. Aotearoa is the Te Reo (Māori-language) name for the colonial name of New Zealand.

understand surf breaks. The research will, in turn, support the effective implementation and uphold the intent of coastal management policies and plans.

1.1. Research Objectives and Questions

This research was undertaken in conjunction with a Ministry for Business, Innovation and Employment (MBIE) Targeted Research Fund project, funded under the enhanced environmental decision-making and behaviour change investment priority. The rationale of the investment priority was that environmental decisions are enhanced and implemented more effectively by: understanding system complexity and interconnectedness; motivators of behaviour change; and, implementation of methods to scale-up or accelerate successful initiatives.

The NZCPS was ground-breaking as the world's first environmental policy to specifically identify surf breaks as protected spaces. Upholding the intent of the NZCPS has been challenging with no clear, quantitative measures or guidelines describing the oceanographic or geomorphic characteristics of the coastal zone that contribute to the functionality of a surf break. This research is focused on developing solutions to aid decision-making by regional, district, or local government, engineers and consultants about activities in coastal areas that encompass or influence the functionality of ANZ's surf breaks. With an aim of providing guidance and improving our current management practices, this research considers the overarching question:

1. **What critical components need to be considered for sustainable surf break management?**

Associated research questions include:

2. **What are the roles and relationships of actors involved in surf break management, including, user groups and stakeholders, experts and consenting authorities?**
3. **How can the key geophysical characteristics and processes that contribute to surf break functionality be better identified and understood?**

The methodology of the MBIE research programme, on which this thesis is based, is comprised of seven categories: study site selection; scoping studies and stakeholder workshops; geomorphological and surf break assessment; data collection; detailed analysis; development of a website and online portal; and the development of management guidelines. This PhD was undertaken in conjunction with the MBIE project. Subsequentially, during the MBIE project, I led the proposal writing, development of strategies and methods and undertook the bulk of analysis personally[2], writing the first and final drafts of all reports. Other project team members provided support, advice, experience, and review.

1.2. Thesis Benefits and Contribution

ANZ provides a unique study setting. It is one of few countries that have included surf breaks in a legislation framework for resource management. ANZ hosts a full range of geomorphic surf break types (Mead, 2000; Scarfe, 2008), with very high-quality surfing opportunities through to accessible learner or 'nursery' surf breaks (Department of Conservation, 2009). While this work is largely focused on ANZ, an effort has been made to understand if the management learnings from this research can be applied overseas.

In summary of the preceding sections, surf breaks have a large and diverse global user base, they enable significant economic opportunity and have been shown to provide health and wellbeing benefits. The range of values associated with surf breaks are epitomised by the inclusion of surfing in the 2020 Olympic Games. This work refers to both surf break and surfing resource, the definition of the latter being a key outcome of this body of work. A surfing resource is the combination of the physical processes (associated with the surf break), sense, feeling, and experience that make it a natural and social resource. Despite the value associated with surfing resources, the destruction and mismanagement history of surf breaks is both long and ongoing. Negative impacts on these coastal resources stem from a lack of education, consultation, understanding and recognition of value. While several works have considered protection mechanisms and some have explored the concept of management, no frameworks or guidance have been developed for the sustainable management of surfing resources.

This thesis provides details of how a set of Management Guidelines for Surfing Resources were developed, a discussion on the potential application of these learnings outside of ANZ and provides novel technical approaches to aid in the management of surfing resources. Before this work, no targeted research to develop implementable guidance and tools for surfing resources had been undertaken, making much of this research project a world first.

During the scoping stage of the overarching research project, environmental scientists were consulted on the proposal. The benefits of this research were noted as:

> *'Being able to understand the key physical characteristics and hydrodynamics of each important break (i.e. what makes it a great break), and therefore what aspects of the environment are most important to protect. Useful guidelines would include some*

[2] An exception being cultural components led by Dr Jordan Waiti.

direction to Council about the specific types of activities that would threaten these values and how these effects can best be predicted and/or monitored' (B. Gibberd (Waikato Regional Council), pers. comm, 15 April 2015).

'Surf breaks are likely to become increasingly recognised by councils and statutory documents, with a number of councils working on developing regionally significant surf breaks…councils have had relatively little to no real world experience in implementing such policy direction… {and} will be looking for guidance around setting appropriate monitoring related consent conditions in regards to activities that have the potential to affect identified surf breaks. Guidelines around appropriate monitoring techniques should be invaluable… Guidance around (the mapping of the surf breaks and swell corridors} would've been very useful when I was spatially defining Auckland's regionally significant surf breaks' (M. McNeil (Auckland Council), 20 April 2015).

'There are no methodologies in any country that provide guidelines on how to sustainably manage surf breaks' (Assoc. Prof. M Davidson (University of Plymouth, UK), pers. comm. April 2015).

Following completion of the project, it was noted that:

'{the guidelines} obviously go where no one has been before in NZ or internationally and will provide a very important benchmark for all future such studies… {the guidelines are} a very important document for NZ surf and hopefully a guide for other countries to follow' (Professor Andrew Short (University of Sydney, Aus.), pers. comm. 26 September 2018).

The contents and purpose of the Management Guidelines for Surfing Resources have since been supported by Aotearoa New Zealand's Department of Conservation.

1.3. Thesis Structure

The main body of this thesis comprises seven peer-reviewed publications which are bookended by a literature review and discussion chapter. The first two publications in Chapters 3 and 4 are focussed on the core deliverables of the MBIE project. The more technical publications in Chapters 6 through 9 were informed by the MBIE research and contributed to the outcomes as referenceable material in the Management Guidelines for Surfing Resources. Table 1.1 provides the order in which the peer-reviewed publications are presented. Chapters 3 through 9 all contribute to addressing Research Question 1. Chapter 2 provides background to the research and literature review. Chapter 3 provides an introduction to the overarching research project (MBIE), describes the methods used, and presents preliminary findings that contribute in addressing research questions 1, 2 and 3. Chapter 4 presents an abridged version of the Management Guidelines for Surfing Resources, with a focus on the novel risk assessment methodology, addressing research questions 1, 2 and 3. Chapter 5 explores the utility of the Management Guidelines for Surfing Resources outside of the ANZ governance framework and provides context for Research Question 2. Chapter 6 contributes to answering Research Question 3 and considers the knowledge gaps in preconditioning features and their role in surfing wave quality. Chapters 7, 8 and 9 consider applied methodologies for day-to-day surfing resource management tools and relate to Research Question 3.

Table 1.1: Chapter number and citation of publications contributing to this thesis.

Ch.	Citation
3	Atkin, E., Hume, T., Mead, S., Bryan, K and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. Coasts and Ports 2017 Conference – Cairns, 21-23 June 2017
4	Atkin, E., Hume, T., Mead, S., Bryan, K and Waiti, J., 2019. Management Guidelines for Surfing Resources. Australasian Coasts and Ports Conference, Hobart, 10-13 September 2019.
5	Atkin, E.A, Reineman, D.R., Reiblich, J, and Revell, D.L., 2020. Applicability of Management Guidelines for Surfing Resources in California. Shore and Beach, 88 (3).
6	Atkin, E.A and Greer D., 2019. A Comparison of Methods for Defining a Surf Break's Swell Corridor. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.
7	Atkin, E.A., Mead, S.T. and Phillips, 2019. Investigations of Offshore Wave Preconditioning. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 78–90. Coconut Creek (Florida), ISSN 0749-0208.
8	Atkin, E.A., Davies-Campbell, J. and McIntosh, R., 2022. Deep Learning Object Detection Application to Surfing Wave Quality. Coastal Engineering, 37.
9	Atkin, E.A., 2021a. Machine-learned Peel Angles for Surfing Wave Quality Monitoring. Australasian Coasts and Ports 2021 Conference – Christchurch, 30 November – 3 December 2021

Appended to this thesis are: The Management Guidelines for Surfing Resources; Published, peer-reviewed papers, co-authored (this author as second author) and coedited (with Professor Karin Bryan) for a Special Issue on Surf Break Management, which are extensively referenced in this work and played a large part in the development of the Guidelines and are integral to the discussion section of this thesis; A popular article related to the project and ongoing research efforts; Co-authorship forms.

2 Literature Review

This chapter provides background regarding the management of surf breaks in ANZ and the unique resource management setting, and compares this to examples of work completed outside of ANZ. This chapter also provides details on the fundamental physical principles concerning surf breaks and how surfing wave quality is objectively quantified.

2.1 ANZ Legislative Setting

ANZ has been innovative in both surf science research and coastal resource management. A result of this combination is exemplified in Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS): *Surf Breaks of National Significance*. The NZCPS is mandatory under the Resource Management Act 1991 (RMA), itself a ground-breaking piece of legislation by being underpinned by the concept of sustainable management and aiming to balance economic and environmental objectives. Having a legislative setting that acknowledges surf breaks and a fact-based approach to resource management readily allows for further research and future improvements, while fast-tracking the identification of shortcomings in management approaches.

The full range of values associated with surf breaks fall under social, cultural, economic and environmental categories (Orchard *et al.*, 2019; Appendix B). These values were most effectively vocalised in ANZ when public input was sought during a scheduled revision of the New Zealand Coastal Policy Statement 1994 (Department of Conservation, 2009). Submissions from the surfing community and well-established surf science experts (e.g., Mead, 2008) resulted in the definition of a surf break and provisions for surf break protection in Policy 16 of the NZCPS (page 19).

'Policy 16: Surf Breaks of National Significance:

Protect the surf breaks of national significance for surfing listed in Schedule 1, by:

(a) *ensuring activities in the coastal environment do not adversely affect the surf breaks; and*
(b) *avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks.'*

The Glossary of the NZCPS provides a definition of a surf break:

'A natural feature that is comprised of swell, currents, water levels, seabed morphology, and wind. The hydrodynamic character of the ocean (swell, currents and water levels) combines

*with the seabed morphology and winds to give rise to a **'surfable wave'**. A surf break includes the **'swell corridor'** through which the swell travels, and the morphology of the seabed of that wave corridor, through to the point where waves created by the swell dissipate and become non-surfable. **'Swell corridor'** means the region offshore of the surf breaks where ocean swell travels and transforms to a **'surfable wave'**. **'Surfable wave'** means a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the wave crest'* (page 28).

The published rationale and guidance of Policy 16 (Department of Conservation, 2011) refers to the integrity of surf breaks and the natural features and processes that maintain them:

'Surf breaks are an important recreational resource for New Zealanders and international visitors, and contribute significant economic and social benefits to both local communities and New Zealand. The integrity of surf breaks, access to them, and their use and enjoyment are vulnerable to adverse effects from development on land and in the coastal marine area. Nationally significant surf breaks therefore receive national policy direction in Policy 16 of the NZCPS 2010.'

'A significant issue for any surf break is that the quality of the surfable wave can be compromised by such things as activities on nearby coastal headlands, up nearby rivers, on the sea bottom and in the swell corridor seaward of the break. The integrity of the natural features and processes that create the wave are critical to maintaining the quality of a surf break. Swell corridors are also dynamic environments and decisions about activities affecting their management can include quite complex considerations.'

In this context, integrity refers to an undisturbed state of natural conditions and processes that allow the environment to function.

Policy 1 of the NZCPS (page 11) defines the *'Extent and characteristics of the coastal environment. Most notably it includes the Coastal Marine Area (CMA); areas where coastal processes, influences or qualities are significant, including coastal lakes, lagoons, tidal estuaries, saltmarshes, coastal wetlands, and the margins of these; elements and features that contribute to the natural character, landscape, visual qualities or amenity values; items of cultural and historic heritage in the coastal marine area or on the coast; inter-related coastal marine and terrestrial systems, including the intertidal zone; and physical resources and built facilities, including infrastructure, that have modified the coastal environment'.*

The descriptive terms that delineate the extent of the Coastal Environment in the NZCPS are very applicable to effective management of surfing breaks. The CMA is defined in the RMA (page 38) and '*means the foreshore, seabed, and coastal water, and the air space above the water—*

(a) of which the seaward boundary is the outer limits of the territorial sea:

(b) of which the landward boundary is the line of mean high water springs, except that where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of—

i. 1 kilometre upstream from the mouth of the river; or

ii. the point upstream that is calculated by multiplying the width of the river mouth by 5.'

The territorial sea is 12 nautical miles from the coastline of New Zealand and delineates the offshore jurisdiction of regional authorities who are charged with managing surf breaks. The CMA is limited in its landward extent and rudimentary when considering the linkages between terrestrial, riverine and marine processes. The NZCPS considers the much more encompassing Coastal Environment which extends landward of the CMA, usually to at least the nearest ridgeline.

The importance of managing the broader coastal environment is most keenly demonstrated at Ebb Tidal Deltas (ETDs), many of which are associated with high-quality surfing waves (e.g., Liria *et al.*, 2009). ETDs are sediment stores created through the deposition of sediment load exiting tidal inlets. Surf breaks associated with ETDs are most often referred to as 'the bar'. Mead (2000) refers to river/estuarine delta breaks, and Scarfe (2008) to river or estuary entrance bar breaks. ETD morphology is moderated by wave action and tidal current, but because of the inherent feedback mechanism (between waves and currents with seabed morphology) ETD morphology influences these primary forcing processes, resulting in changes to how sediment is reworked. Changes in morphology will also influence surfing wave quality. Effective management of delta breaks requires the consideration of the processes and activities being undertaken in the catchments draining into the estuarine system. The CMA description in the RMA provides some allowance for this (e.g., 1 kilometre upstream), however, the Coastal Environment is essentially all-encompassing and includes *'elements and features that contribute to the natural character, landscape, visual qualities or amenity values.'*

Surf breaks are standout features of any coastline as they require specific geomorphological and met-ocean conditions to produce waves that break in a manner conducive to surfing, this is evidenced by a lack of surfing on the vast majority of coastlines. The 17 Surf Breaks of National Significance (SBNS), designated under the NZCPS, cumulatively occupy ~4.5 km, 0.0003 %, of the ANZ coastline.

There are a number of cultural and historic heritage ties to surfing in ANZ in both historical Māori culture (Beattie, 1919; Best, 1924) and through Surf Life Saving (Appendix A). This ties surf break management to Policy 2 (page 11) the Treaty of Waitangi, tangata whenua and Māori, which ensures the traditional custodians of the land have meaningful involvement in decision-making and are able to exercise kaitiakitanga (guardianship).

'Built facilities, including infrastructure, that have modified the coastal environment' (Policy 1) are not always considered conducive to surf breaks and a natural surfing experience, but there are many examples of surf breaks resulting from modified coastlines (e.g., Mead and Atkin, 2019; Scarfe *et al.*, 2009a, 2009b).

Policy 3 of the NZCPS (page 12) is '*Precautionary Approach:*

(1) Adopt a precautionary approach towards proposed activities whose effects on the coastal environment are uncertain, unknown, or little understood, but potentially significantly adverse.

(2) in particular, adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change, so that:

- *(a) avoidable social and economic loss and harm to communities does not occur;*
- *(b) natural adjustments for coastal processes, natural defences, ecosystems, habitat and species are allowed to occur; and*
- *(c) the natural character, public access, amenity and other values of the coastal environment meet the needs of future generations.'*

While surf breaks are largely finite and relatively scarce along the coast, there is, in most cases, very little to no data pertaining to the existing wave quality, breaking patterns, physical drivers, and socioeconomic importance. Surf breaks can also be associated with sensitive features of the coastal environment, such as ETDs.

Little work has been done in the area of surf breaks and climate change. Reineman *et al.* (2017) suggest that surf breaks in California will be vulnerable to the effects of climate change after interviewing more than one thousand California surfers and, by extrapolating tidal influences on surfing experience to simulate the effects of Sea Level Rise. The results suggest that by 2100 16% of surf breaks would be 'Endangered' due to drowning and 18% would be 'Threatened'.

Policy 13 (page 17) '*Preservation of natural character*' of the NZCPS specifically identifies surf breaks as part of the natural character of the coastal environment. Policy 13 aims to preserve and avoid adverse effects of activities on natural character, and includes natural elements, processes and patterns; geological and geomorphological aspects; natural landforms such as headlands, peninsulas, cliffs, dunes and reefs. Reef break is a geomorphological type of surf break (Mead, 2000); in ANZ these reef breaks will be exclusively rocky reefs, while in the tropics, coral reefs provide the seabed substrate for many of the world's best surfing waves. Headlands and peninsulas can play a significant role in surf break functionality and can result in another surf break typology: Point break. Benedet *et al.* (2007) also consider headland bay as a subcategory of beach break (Mead, 2000; Scarfe, 2008). Mead (2000) considered headlands as large 'wedges', one of the seven functional components of surf breaks (Mead and Black, 2001a, 2001b), where the subtidal component of a headland generally needs to be misaligned with incident wave crests. Mead (2000) further describes headlands as being capable of refraction compensation where the isobaths of the large-scale wedge continually bend away from the favoured orthogonal direction of incident waves to prevent the wave from closing out (breaking simultaneously along its length) and maintain a surfable peel angle. Phillips and Mead (2008) showed that large changes to the seabed offshore from sand moving along the coast or around headlands can have profound effects on surfing wave quality.

Policy 15 (page 18) aims to protect natural features and natural landscapes, including seascapes. The policy specifies the assessment of natural features including geology and dynamic components; aesthetic values including memorability and naturalness; transient values, including the presence of wildlife or other values at certain times of the day or year; whether the values are shared and recognised; wild or scenic values. The wording around Policy 15 is significant with the inclusion of 'assessment' and relates to Policy 3 Precautionary Approach, ensuring that resources are fully understood. Surf breaks are certainly a product of geological processes and are dynamic in both space and time on a range of scales. Certain surf breaks only work under the rarest of conditions (considering wave heights, period and directions; wind, and tide), and can be reliant on met-ocean conditions 1000s of kilometres away. Other surf breaks are only surfed seasonally e.g., reliant on tropical cyclones.

ANZ's national policy is both explicit in the statutory protection of surf breaks and implicit in the sustainable management of surf breaks; and there is an emphasis on subnational authorities (regional, district and city councils) to be effective in surf break management by implementing policies and plans (Regional Policy Statements, Regional Plans, Regional Coastal Plans, District Plans and Unitary Plans). Such implementation may include rules in plans that control activities to avoid, remedy or mitigate effects on surf breaks. At the regional level, there is scope to specify the methods to be used to identify and protect surf breaks within a policy statement.

While this framework is ground-breaking, in many cases how it is implemented from jurisdiction to jurisdiction has been very different. Orchard (2017a) examined case studies of surfing-related policy instruments in Australasia and found inconsistencies in the scope and design of implementation methods at a regional level. Orchard *et al.*, (2019; Appendix B) considered the concept of Surf Breaks of Regional Significance (SBRS), a strategy that has been implemented in ANZ without formal consideration for a method. Six regions included mechanisms for the inclusion of SBRS, either within a regional policy or coastal/environmental/natural resources plan; with the methods used ranging from a blanket type approach where all surf breaks within a surf guide are included plus those identified through local knowledge holders (e.g., Coombes and Scarfe, 2010), to surveys and assessment criteria (e.g., Orchard, 2017b).

Despite the legislative framework to effectively manage surf breaks, and policies and plans being implemented at the sub-national scale, to date, at least 40 surf breaks in ANZ have been the subject of debate due to proposed activities in the past few decades, including 6 of the 17 Surf Breaks of National Significance (Mead and Atkin, 2019; Appendix C).

2.2 Surf Science Fundamentals

Compared to other research disciplines, surf science is a relatively new field. Surf science is firmly rooted in physical oceanography, which itself grew into a discipline in the 1940s due to the advantage armed forces gained from having a better understanding of ocean dynamics. An understanding of the physical and dynamic attributes of surf breaks is imperative to characterisation and effective management. Compilation of surf science fundamentals has been undertaken several times, including in books (e.g., Mead and Borrero, 2017), journal articles (e.g., Scarfe *et al.*, 2003a; 2009a, 2009b, 2009c; Mead and Black, 2001a, 2001b, 2001c; Hutt *et al.*, 2001; Mead and Atkin, 2019), research theses (e.g., Atkin, 2010; Johnson, 2009; Scarfe, 2008; West, 2002) and technical reports (e.g., Scarfe *et al.*, 2003b; Blacka *et al.*, 2013).

A commonly distributed image of surfing is where the surfer is riding inside the hollow, or vortex, created by the breaking part of the wave. This is often referred to as a barrel or tube. Riding inside the barrel is a critical manoeuvre, and so, wave shape plays an important role in surfing performance. Both peel and shape are a critical function of how the seafloor, or bathymetry, and incident waves interact. The work of Mead (2000), and more concisely, Mead and Black (2001a, 2001b) exposed a series of commonly occurring mesoscale geomorphic components from which surf breaks are comprised, namely: ramp, platform, wedge, ledge, focus, ridge and pinnacle. Mead and Black (2001a) created two categories for the components: those which break the wave, and those which precondition the wave prior to breaking.

2.2.1 Preconditioning

Walker *et al* (1972) were the first to describe wave transformation processes prior to breaking with reference to a specific surf break, what we now refer to as preconditioning. Walker *et al* (1972) describe the convergence of wave energy over a ridge (focussing) and divergence over a trough, which results in along-crest variations in wave height. Walker *et al* (1972) note that diffraction transmits wave energy laterally along the wave crest which would act to smooth the along-crest wave height variations. This latter process was later discussed in conjunction with activities/developments on the coast (Black, 2007; Mead, 2013) and the management of surf breaks (Atkin *et al.*, 2015; Atkin and Mead, 2017; Atkin *et al.*, 2021), and a significant distance may be required before the waves re-conform to a pre-disturbance condition, but no work has systematically quantified the restoration process with respect to surf breaks.

Battalio (1994) and Battalio and Trivedi (1996) describe the complex hydrodynamic and sediment transport processes occurring around the San Francisco Bar in Northern California. Ocean Beach on the southern side of Golden Gate is known for heavy breaking A-frames and the ability to hold larger swells than other beach breaks in the area. The term A-frame describes a peak (the initiation of breaking) that breaks both to the left and to the right. The ebb tidal delta (San Francisco Bar) extends more than 5 km from the shore. Battalio and Trivedi (1996) state that focusing occurs with incident waves from most directions and the complex bathymetry results in 'multiple wave travel paths'. Evident in the aerial photographs presented in Battalio (1994) and Battalio and Trivedi (1996) are wave-wave interactions occurring some distance from the shore at Ocean Beach, which results in an amplified breaking wave height at the location of wave crossing, resulting in a very 'peaked wave form' (Battalio, 1994).

Mesa (1996) describes and monitored a subtidal deposit of 0.98 Mm^3 of material at Newport Beach, California, US between 1991 and 1995. During this time Mesa (1996) observed waves that peel in a fast spilling or plunging manner and noted that the surfing conditions were enhanced. This enhancement was attributed to a scattering of the wave field as incident wave crests interacted with unevenly distributed spoil mounds creating multiple peaks.

Raichle (1998) undertook a numerical modelling study to better understand Mavericks in Half Moon Bay, CA, USA, which is one of the world's premier big wave surfing locations. By observing wave direction vectors and wave height modulations, the study identified an antecedent headland feature that acts as a focus to create a large zone of increased wave heights at Mavericks (also discussed in Mead *et al.*, 2003). Raichle (1998) states that the safe, relatively quiescent zone adjacent to the surfing area at Mavericks is not a true channel, but a function of the focussing that reduces wave heights feed the Mavericks peak. This work also highlighted the focus sensitivity to wave direction and period, where sensitivity to direction decreases with increasing wave period. Raichle (1998) states that the deeper bathymetric features become 'activated' with an increasing period, in the terms of Mead and Black (2001b), the higher wave period allows wave crests to align to a favoured orthogonal direction. Mead *et al.* (2003) later noted that the focus at Mavericks works in conjunction with a submarine canyon that also influences the magnification of wave heights.

Raichle (1998) also highlighted the local increase in wave heights at 'the Poles' in Mayport, Atlantic Beach, FL., USA, attributing wave amplification to dual focussing over lobes that create two peaks that intersect inshore to form the surf zone. One part of the focussing described in Raichle (1998) starts in the area of what would be a terminal lobe, the other occurs on the relatively gentle slope of a channel margin linear bar.

Bancroft (1999) undertook monitoring of Cable Station, a Multi-Purpose Reef (MPR) built in western Australia. The MPR was designed as a wave breaking component (Mead and Black 2001a; 2001b). Yet, Bancroft (1999) reported modification to the wider wave climate, in particular, the popular beach breaks inshore of the MPR. The only reference to the type of modification is that the shore break produced larger waves which were attributed to the focusing effects of the MPR.

Mead (2000) undertook bathymetry surveys and numerically modelled 44 high-quality surf breaks around the world. At Pipeline, one of the world's most distinguished surf breaks, Mead (2000) found that in the area where surfing takes place the isobaths of the reef are essentially parallel to the beach and show no pronounced functional components or alongshore discontinuities. The reef break at Pipeline is well known for its singular A-frame peak that offers both a left (Pipeline) and a right (Backdoor), depending on the swell direction. Mead (2000) categorises Pipeline as a large focus and attributes the distinctive breaking profile of Pipeline to the offshore, deeper bathymetric features. The focus is a shore normal ridge that extends offshore. Incident waves are focussed on the ridge, creating localised increases in wave height, and a relative loss of wave height from adjacent parts, which leads to an alongshore wave height gradient. Wave height at the peak of Pipeline is notably larger and reduces along the wave crest on a planar beach. With a shore-normal incident direction and depth-limited breaking as a function of wave height, a wave height gradient will result in waves that peel. Mead (2000) also references Black *et al.* (1998) when discussing the efficacy of a focusing feature, noting that over-focusing can extract wave energy along the wave crest so that the focussed peak becomes divorced from the rest of the original wave crest. The preconditioning features of Mead (2000) are Ramp, with a scale range and contour normal gradient range of 100->10,000 m^2 and 1:40-1:80, respectively; and Focus, with a scale range and contour normal gradients range of 10-1,000 m^2 and 1:10-1:80, respectively. However, components, such as the San Francisco Bar (Battalio, 1994; Battalio and Trivedi, 1996), under the title of Focus, would have scale ranges of several orders of magnitude greater than 10,000 m^2.

West (2002, West *et al.*, 2003) conceptualized the construction of a wave focusing artificial reef. The work considered a range of lengths, widths and depths superimposed on a 1:20 slope and simulated a 1 m wave at 8 s. West (2002) developed dimensionless relationships using reef geometry and the degree of wave height focussing and the distance that the wave breaking location was displaced. The work concluded that a reef height:width:length ratio of 1.5:10:40 under the simulated wave conditions would improve surfing conditions, and that the amount a wave will peel reduces with increasing distance between the offshore toe and the shoreline. However, the work included some simulations where waves were breaking on the design reef and this does not match the description of an offshore feature that exclusively preconditions prior to wave breaking.

Mead *et al.* (2003) considered wave focussing on a broader range of scales, from localised features specific to a surf break, through to continental shelf scale processes which can affect large areas of the coast. Offshore ridges, sea mounts, the edges of canyons, ebb tidal deltas, large-scale offshore banks and small-scale reefs can all contribute to the incident wave conditions of a surf break. Preconditioning cases highlighted by Mead *et al.* (2003) include:

- Rincon, Southern California, USA. One of the best examples of large, offshore, continental shelf scale preconditioning is the focusing of waves in the Santa Barbara Channel in Southern California. Simulations of the submarine ridge, in ~100 m water depth, showed the focusing of wave energy toward Rincon Point, which is considered to be a world-class surf break, and would certainly classify as Nationally Significant in ANZ.
- The Mayport Poles, Atlantic Beach, Florida, USA. Numerical modelling of the river delta of the St. Johns River indicated amplification of wave height by 1.5, relative to adjacent wave characteristics. The Mayport area is considered to be the most consistent surf break in North Florida and can handle the large swells, during which many beaches become un-surfable. The waves have an A-frame, peaky, character.
- Matakana Island, Bay of Plenty, ANZ. The high-performance surfing area of the barrier island of Matakana is situated on the northern side of the entrance to Te Awanui (Tauranga Harbour). The headland control of the Mauao results in a constricted ebb tidal delta (Hicks and Hume, 1996). Matakana Island is known for barrelling A-frame peaks. Mead *et al.*, (2003) attribute the A-frame peaks, not to the nearshore bathymetry, but to the ebb tidal delta, and made comparisons to the wave-wave interactions observed at Ocean Beach (USA; Battalio, 1994, Battalio and Trivedi, 1996).

- Raratoka, also known as Centre Island, is located ~7 km offshore from the mainland of Te Waipounamu (South Island), ANZ. Mead *et al.* (2003) refer to the focussing process at Raratoka as extreme. The location is one of ANZ's established big wave surfing locations (Atkin *et al.*, 2021 and references therein), however, Rust and Kirkham (2009) and NZS (2014) indicate that Rarotoka is also surfable when not in the big wave category, with 'swell of six feet or more' resulting in 'powerful left-breaking waves' (Rust and Kirkham, 2009). Mead *et al* (2003) describe an extensive undersea ridge, ~4 km in length, which runs offshore from the southwestern tip of the island. The ridge is aligned toward the predominant swell direction from the southwest. Simulations of waves using both phase-averaged and phase-resolving numerical models showed very localised focusing of wave heights and wave height gradients/variability (Mead *et al.*, 2003), much like the processes described by Walker *et al.*, (1972).

In Tūranganui-a-Kiwa (Poverty Bay) on the east coast of Te Ika-a-Māui (the North Island) of ANZ there is a succession of reefs, Tokumaru, Hawea and Temoana, colloquially known as the 'Foul Grounds'. The reefs are ~3 km from Midway Beach, one of the 'town beaches' of Gisborne (Peryman, 2011a). Generally considered accessible for the average surfer, Midway Beach provides right and left-handers, with multiple peaks (take-off areas). One particular stretch of Midway Beach is named Midway Pipe (also known as 'the Pipe'; 'Gizzy Pipe') and is associated with a main peak that is known to provide high-performance waves for advanced and expert surfers.

The bathymetric configuration at Midway Beach from nautical charts does not indicate any notable breaking functional component and no significant alongshore discontinuity in isobaths, it is essentially a planar beach. Beamsley and Black (2003) ran refraction/diffraction and phase-resolving models for Tūranganui-a-Kiwa. Beamsley and Black (2003) showed that the offshore configuration of submerged reefs that extend to the southeast from Midway Beach precondition the incident wave climate to produce more favourable surfing conditions. The reef complex focuses wave energy into the area of Midway Pipe, reportedly increasing the relative wave height by 2. A reduction in wave celerity over the reef also results in the bifurcation of the wave crest, also referred to as crest snapping. This combination of increased wave height and crest snapping was predicted to create alongshore wave height gradients. Beamsley and Black's (2003) model simulated a left and right breaking peak at Midway Pipe with peel angles conducive to surfing (Hutt *et al.*, 2001) which was considered consistent with observations. The model also simulated low peel-angle 'closeout' conditions along much of Midway Beach.

Pitt (2009) identified 26 Australian beaches that are directly influenced by offshore features, referred to as 'Bomboras'. The work largely focuses on two surf breaks in New South Wales: North Narrabeen and The Peak. Pitt (2009) proposes that '*bombora controlled beaches*' are popular with surfers because:

1. *''certainty', the bomboras focus advancing waves to a more certain location on the beach*
2. *'swell magnet', wave height is larger by a factor of 1.25 to 2, depending on wave period and swell angle*
3. *'length of ride', a wave is more likely to break as a 'peak' (rather than 'closeout') and therefore offer a longer length of ride*
4. *'safety', at North Narrabeen and the Peak, surfing action takes place over a sand foundation, the deep outer reefs are rarely surfed, except on days with extra large waves, it is safer to wipeout on a sandy beach than a stone reef'* (page 9)

Pitt (2010) proposed the deposition of 24,000 m^3 of dredged material in a shore normal mound extending 400 m offshore from the 4 m to 11 m contour at Cronulla beach, an Australian surf reserve in New South Wales. Whilst referencing literature regarding surfing wave conditions, multipurpose reef design and shoreline response, Pitt (2010) did not present a numerical or physical model of the proposed deposition. Despite this, Pitt (2012) reported that 50,000 m^3 of spoil was deposited at North Cronulla which improved surf conditions, and eventually dispersed, subsequently nourishing the beach. No published evidence of these findings could be located (Dredging Today, 2012).

Aramoana Spit (Otago, New Zealand) is a sand-bottom beach break known for its hollow and powerful waves associated with 'wedging peaks[3]' (Morse and Brunskill, 2004). The nearshore area where surfing takes place is devoid of the breaking functional components required to produce these types of waves (Kilpatrick, 2005; Scarfe *et al.*, 2009b; Mead and Black, 2001b). The beach at Aramoana is located in the lee of both an ebb tidal delta that extends from a headland (Taiaroa Head) at the entrance of a large, drowned river valley estuary (Otakou), and a dredge spoil disposal ground. The characteristics of the waves at Aramoana are reliant on preconditioning that involves multiple seabed features (ebb tidal delta and the disposal ground), which result in wave focussing, alongshore wave height gradients, wave-wave interactions and/or bifurcation of wave crests (MSL, 2014; Mead and Atkin, 2019).

Another nearby dredge material disposal site, northwest of Aramoana, is Heyward's. The Heyward's site has been shown to influence the surf break at Whareakeake (aka Murderer's).

[3] "Wedging peaks" refers to the triangle or wedge shape of the wave face formed where wave height is locally increased creating a "peak". The peak often refers to the part of the wave which breaks first and is also known as the take-off.

The Heyward's site is some ~2 km from the surf break and results in wave focusing/defocusing and/or dispersion/splitting because the site is located in the swell corridor of Whareakeake (MSL, 2014; Mead and Atkin, 2019).

In 2011 a 6.3 M earthquake occurred in Christchurch, ANZ, causing widespread damage and producing an estimated 1,000,000 tonnes of debris and rubble. With a view to finding sustainable solutions for the disposal of the rubble, which could also help a post-earthquake economy, Mead *et al.* (2011) undertook simulations of a hypothesised offshore feature at Sumner Beach. The simulations showed that a 100,000 m^3 feature could positively alter surfing wave conditions at Sumner Beach. While the initial modelling results were positive, the approach was relatively arbitrary and did not provide any explicit design limitations.

For Lyall Bay, Te Ika-a-Māui (North Island), Danish Hydraulic Institute (2016) proposed a 17,000 m^3 wave focussing structure to increase 'localized wave peakiness'. The work presented a preliminary concept and no technical rationale behind the design and a limited literature review. The motivation behind the structure was to mitigate the loss of surfing amenity introduced by the proposed Wellington Airport Runway extension. The design report states that the structure would generate a localized wave peak and provide longer rides. The phase resolving model results showed that the structure initiates a number of cases of wave breaking further offshore (than without the structure); but breaking wave paths further inshore are more numerous. The location of a peak where this is occurring does not seem well defined, and this is corroborated by the phase-resolving model results. Like Mead *et al*. (2011), conceptually the proposal of Danish Hydraulic Institute (2016) has the potential to have a positive impact on surfing amenity by increasing the number of surfable waves directly in the lee of structure. However, there remain many unknowns, including shoreline response, the actual mechanics of breaking (i.e., are there wave-wave interactions, what type of wave shapes are to be expected?), what are the impacts on existing surfing amenity elsewhere in the bay, noting that the work predicted a reduction in the number of rides and wave heights at Lyall Bays premier peak, the Corner, and what are the impacts on beach safety when modification longshore wave height gradients can force the formation of rips. Danish Hydraulic Institute (2016) acknowledges that further investigation would be needed to understand many aspects of establishing such a structure.

2.2.2 Breaking

The common qualitative system of breaking wave categories was established in the 1960s (Galvin, 1968; Wiegel, 1964), and quantitative methods to link the qualitative terms followed in the 1970s (Battjes, 1974; after Iribarren and Nogales, 1949). It was not until Mead (2000;

Mead and Black, 2001c) that this paradigm was examined in more detail with a focus on waves for surfing.

While modern-day surfers attempt to ride almost every type of wave: spilling, plunging, collapsing and even surging (Galvin, 1968; Wiegel, 1964); the plunging category is considered the most sought after for high-performance surfing. Mead (2000) recognised, along with most experienced surfers, that the plunging category is very broad in terms of wave shape. Mead and Black's (2001a, 2001b, 2001c) work considered wave conditions and seafloor shape, or bathymetry, of more than 40 international surf breaks. Mead and Black (2001c) showed that a plunging wave's 'vortex ratio' (after Sayce, 1997; Sayce *et al.*, 1999) can be predicted using the orthogonal seabed gradient – the gradient along a line perpendicular to the wave crest. The vortex ratio is the length-to-width ratio of the area underneath the breaking part of the wave and indicates the 'roundness' of a wave as it breaks. As the vortex ratio approaches 1, the tube shape becomes more circular and less elongated, and breaking is more intense. Breaking waves with smaller vortex ratios are more likely to collapse. Waves with vortex ratios larger than 3 are gently plunging or spilling. The relationship Mead and Black (2001c) established between the orthogonal seabed gradient (X) and breaking intensity (Y) is:

$$Y = 0.065X + 0.821$$

Mead and Black (2001c) related the shape of different categories of surfing waves with surfing terminology and provided examples of surf breaks fitting each breaking intensity.

Learner surfers often begin with large, soft malibu-style surfboards that are used to catch the whitewater bore. This level of performance does not require any discontinuities in the bathymetric profile or wave height gradients, but simply a planar shore and wave to break far enough away from the subaerial shoreline to provide enough time for the act of catching the wave to be considered a ride, whether the participant stands up or not. Some crafts, such as longboarders and stand-up paddle boarders, can catch and ride waves that are barely breaking at all. These examples of wave riding are less dynamic than surfing in and around the breaking part of the wave, or vortex, which has certainly been the focus of mainstream surf competitions and media.

For surfing in and around the vortex to take place, the breaking part of the wave must peel. The peel angle is defined as the angle between the trail of broken white water and the crest of the unbroken part of the wave (Walker *et al.*, 1972; Walker, 1974). Peel angle is directly related to the rate at which the breaking part of the wave translates, that is the speed at which a wave is breaking.

If a wave breaks simultaneously along the length of its crest then the peel angle is zero degrees. This scenario is termed a 'close-out' in surfing culture. If the breaking part of the wave does not translate along the crest at all then the peel angle is 90 degrees, therefore a wave with a low peel angle breaks faster than that with a high peel angle. Waves can peel either as a 'left-hander' or a 'right-hander', and the direction is relative to a surfer paddling for the wave (generally when viewed offshore to onshore).

Walker (1974) and later Hutt *et al.* (2001) categorised surfing waves in terms of difficulty based on the peel angle. Hutt *et al.*'s (2001) scheme considers skill levels from absolute beginner to waves beyond the current highest skill level. Mead and Borrero (2017) note that while Hutt *et al.*'s classification scheme is a useful tool, it is based upon a single peel angle value for a particular surf break. Surf breaks can have several 'sections' with different surfing characteristics. Moores (2001) considered section length and peel angles using videography techniques. Moores' work validated the scheme of Hutt *et al.* (2001). While the understanding of surf break dynamics was increased, there remains a void in information on how peel angles change over larger temporal scales and conditions.

Ride length is also considered an important parameter when participants assess surfing wave quality (Pitt, 2009) and those designing manmade surf breaks (e.g., Black *et al*., 1998; Hearin, 2009). In a study of surfing competition scores, Peirão and Santos (2012) showed a very significant relationship between scores and length of ride, and early competitions included length of ride as part of the judging criteria (Orams and Towner, 2012). However, surfable waves come in all different shapes and sizes and some participants specialise in waves with very high breaking intensities but have a short ride length. The choice of wave in this case would be seen as poor quality if length was considered as the primary metric of wave quality. This makes ride length as a metric for quality more subjective than peel angle and wave breaking shape. However, it is important to be able to measure the length of surfable waves to establish a baseline characteristic. Aerial/satellite photography (Atkin *et al*., 2021), remote camera monitoring sites (Atkin, 2010) and surfer GPS (Borrero *et al*., 2019) have all been used to quantify ride length.

Comprehensive characterisation from aerial and satellite images may be difficult in some locations as the number of images that include surfable waves, and therefore points in time, may be limited. Remote camera monitoring sites, if set up suitably can provide a large, high temporal and spatial resolution dataset that will capture all conditions, but have a relatively significant overhead associated with installation, setting up and the ongoing handling of data for tangible image products. The data collected from GPS carried by surfers can be used to characterise waves that are surfed, as opposed to a theoretical maximum for a surfable wave, but are highly dependent on skill level and only capture a snapshot of all conditions.

2.3 Surf Break Management in ANZ

Peryman (2011b) provides a timeline describing the events leading up to the inclusion of surf break terminology in the NZCPS. The participation of the surfing community is described as seminal in this process; however, mismanagement of the Whangamata Bar is noted as a key issue associated with this participation (Peryman and Skellern, 2011). Issues surrounding the Whangamata Bar have been relatively well documented (Atkin *et al.*, 2013; Edwards, 2013; Hewett, 2011; Mead, 2008; Scarfe *et al.*, 2009c). There were, however, management issues in ANZ that predate those associated with Whangamata and the revision of the NZCPS. The following subsections provide details of four of the more prominent management issues.

2.3.1 Ti Point

The demise of Ti Point, or Omaha Bar, as a surf break has been attributed to anthropogenic activity (Rooney, 2011; Wannasurf, 2022), and while Williamson and Williamson (2014) indicate this is the case, they also provide testimony that anthropogenic activity also created the wave. Ti Point is located on the northeast coast of Te Ika-a-Māui, at the northern end of Little Omaha Bay. Anecdotal evidence suggests, and aerial photos indicate, that there was only a low-profile ETD at the entrance to the Whangateau estuary during the 1960s and early 1970s; but by the mid-1970s the ETD was 'big' and 'getting better and better', in terms of surfing wave quality. Williamson and Williamson (2014) state more than 380,000 m^3 of sand was dredged from outside the harbour entrance between 1942 and 1963. Riley *et al.* (1985) estimated that 60,000 m^3 was dredged between 1959 and 1963, and between 1963 and 1978 the dredged pit at Ti Point had begun to infill, with an estimated 450,000 m^3 (± 80,000 m^3) added to the area of the ETD. Photographic evidence certainly corroborates an extensive ETD relative to the 1963 configuration.

The Whangateau sand spit was developed into residential lots in the late 1960s, with a causeway across the inner Whangateau estuary being constructed for access. Williamson and Williamson (2014) state that '*between 1966 and 1976, it is estimated that 150,000 m^3 of sand was lost from the tip of the spit, 200,000 m^3 from the foredunes, and up to 1,000,000 m^3 from the beach itself*' (page 4). The protection of residential lots that were developed on the sand spit was addressed with a wooden sea wall, behind which marram grass was planted. These land defences failed in storms during the 1970s, with the foundations of one of the first houses built there being compromised. Subsequently, Beca Carter Hollings and Ferner were contracted to build groynes in 1978 to stabilise the sand spit. Following completion, 400,000 m^3 of sand was dredged from the inner Whangateau and placed between the groynes. Surfers who frequented the Ti Point Bar report that this was the beginning of the end

(Williamson and Williamson, 2014). According to an interviewee in Rooney (2011) the groynes to stabilise the barrier spit and land defence structures to protect residential developments in the 1970s, resulted in a seaward accumulation of sand that decreased the quality of the Bar.

The photographic and anecdotal evidence indicates a surf break composition that provided a high-quality wave, coincident with significant, distal, proximal and direct anthropogenic activity to the surf break area. The case raises several questions about activities within the CMA, the appropriateness of design, but also being able to distinguish between real and perceived drivers of change in the coastal environment.

2.3.2 Waikeri

More commonly known as Manu Bay, Waikeri is located on the west coast of Te Ika-a-Māui, to the south of the entrance to Whaingaroa (Raglan) Harbour. It is the last in a succession of three point breaks, all Surf Breaks of National Significance. The point break at Manu Bay is a rocky reef with andesitic boulders that fan out from above the high tide mark down to depths of 3-6 m. From the toe of the reef, a sand platform extends offshore. At the eastern end of the point, a breakwater was constructed in the 1960s to provide shelter for a boat ramp. The breakwater has caused a large scour hole on the structure's western side resulting from increased offshore-directed currents induced by wave setup between the breakwater and adjacent land, and wave reflections ('backwash') from the breakwater itself. The breakwater and boat ramp has shortened the length of the surfable ride by up to 100 m (Scarfe *et al.*, 2009a). The presence of the breakwater impedes wave-driven currents, which are redirected offshore. This prevents the movement of boulders along the upper shore, leading to erosion on the eastern side of the boat ramp (Mead, 2020). During construction, sub and intertidal substrates were excavated from a ~2,000 square metre area, creating a 50 m (approx.) wide gap in the pre-construction morphology (Scarfe *et al.*, 2009a; 2009c).

The original boat ramp at Manu Bay consisted of simple timber retaining walls and the wave was reported to have been surfable to the east end of the bay (Puriri, 2015). In the late 1960s, the contemporary boat ramp and breakwater at Manu Bay were first constructed. The infrastructure has undergone routine maintenance since its inception. Following structural failures at the seaward end of the breakwater, in 2016 the breakwater was replaced with a new structure. The new breakwater is inside the original breakwater's footprint on the north-western side, and outside the existing footprint on the south-eastern side, due to the proposed design being linear, rather than bending northward. The design height and width of the breakwater are consistent with the original, although the flanks of the breakwater are less steep.

Multiple local stakeholder meetings have been undertaken to address criticisms regarding the efficacy of the breakwater in protecting the boat ramp. At the time of writing, detailed investigations to determine potential modifications to the breakwater and boat ramp configuration are being considered. The situation is further complicated by the terminal end effects of building a cross-shore structure in the surf zone. More than half a century of the transport processes being inhibited has resulted in down-coast erosion. Mass blocks were installed east of the boat ramp to protect the land, but the material deficit will continue and impacts are likely passed down drift.

2.3.3 Whangamata

The marina development in the Whangamata Estuary was very controversial and the management approach, consent conditions and surf break dynamics have been discussed in numerous published and unpublished works (Atkin and Greer, 2013; Atkin *et al.*, 2013; Campbell, 2021; Edwards, 2013; Hewett, 2011; Hume *et al.*, 2019; Peryman, 2011b; Scarfe, 2008; 2009a; 2009c; Skellern, 2011; Skellern *et al.*, 2013).

The consenting process for the marina was extensive (Wycherley, 2003). The application was elevated from Environment Court, where the proposal was rejected, to a judicial review and High Court proceedings, before being granted (Christensen *et al.*, 2007). Several stakeholders opposed the development including local Iwi and surfers. Concerns included the destruction of traditional fishing grounds, disrespect for papatipu (ancestral ownership); destruction of significant ecosystems; and removal of public access. Following non-notified changes to the development plans, the level of opposition eventually resulted in a protest in 2008 which led to a review of the consent process (Thomberson, 2012). Construction began in the same year and the bund connecting the marina to the estuary was opened in 2009.

Where the Whangamata estuary meets the Pacific Ocean there is an ebb tidal delta, which is referred to as the Whangamata Bar and well known for the high-quality waves for surfing (Bhana, 1996; Mead and Black, 2001a, 2001b, 2001c; Morse and Brunskill, 2004; Rainger, 2011). Access to the marina was made by dredging ~32,000 m^3 of material to create a channel that requires periodic maintenance dredging, initially set to 2,000 to 3,000 m^3 per annum, in 2010 this was increased to 10,000 m^3. Consent conditions relevant to the surf break included the development of an appropriate plan to monitor the ETD to determine if dredging and construction have had any long-term adverse effects. A plan was developed to undertake bathymetric surveys of the ETD and inlet throat area. The surveys were to commence prior to construction and continue at 3 monthly (first 2 years) and 6 monthly (following 3 years) intervals.

The case of Whangamata raises a litany of management issues, from treaty obligations to basic scientific investigation (Pearce, 2013; Shand, 2008). There was a lack of baseline characterisation meaning that observations were incomparable, and the monitoring methodology was only focused on bathymetry, the sampling frequency of which was inappropriate for a highly dynamic, sediment transport-dependent system, that was little understood.

Whangamata Bar eventually became one of the 17 Surf Breaks of National Significance. In terms of preserving a feature of outstanding natural character, it was too little, too late. In 2012 the Surfbreak Protection Society (SPS) presented to the Hauraki Gulf Forum which triggered a review of the maintenance dredging consents. The review initiated a 4-year photographic study from 2013-2017 which, SPS believe, shows a direct link between dredging activity and morphological change in configurations of the flood and ebb tidal deltas and the tidal inlet throat which directly affect surfing wave quality. To date, no conclusive evidence has been published to show if the marina construction or ongoing maintenance dredging has had an effect on surfing wave quality.

2.3.4 Aramoana and Whareakeake

Both surf breaks are anthropogenically modified and Surf Breaks of National Significance. The embayment of Aramoana is delineated by Heyward Point to the northwest and a 900 m long rock groyne to the southeast. Construction of the groyne or mole started in 1884 (Davis, 2009) with the aim of controlling the estuary's ebb jet. Dredge spoil from Otakou (Port Otago) has been disposed of in the swell corridors of both surf breaks since the 1980s. Anecdotal evidence suggests that following the early period of disposal surfing conditions were premium, later reports from the surfing community indicated a reduction in surfing wave quality (Mead and Atkin, 2019).

Port Otago Ltd applied for consent to increase the quantity of material disposed of at the spoil grounds offshore of Aramoana and Whareakeake. This drew objections from a range of stakeholders, and following an appeal, caucusing, council hearings and eventually mediation, an inclusive working party was formed. The working party agreed to a 3-year temporary permit with greatly reduced disposal at the nearshore site of Aramoana; monitoring at both Aramoana and Whareakeake including topographic and bathymetric surveys, photographic records, nearshore ecology; and numerical modelling to determine the impacts of nearshore disposal.

The working party subsequently agreed that no material would be disposed of at Aramoana for the first 2 years. During this time, surfing conditions were reported to have improved. Broadening the collective understanding of the Heyward's disposal site and how it interacts with Whareakeake led to modifications of the consented area to better manage the surfing wave quality, including improvement by increasing the degree of wave focusing.

The case of Aramoana-Whareakeake and Port Otago is a unique win-win management example (Mead and Atkin, 2019; Mead *et al.*, 2021). The understanding of surf break mechanics and sensitivity was late in the process. These cases showcase the value of detailed characterisation and the requirement for establishing swell corridors, given the significant role of preconditioning and, in the case of Whareakeake, processes that were relatively unknown prior to further investigation.

2.3.5 ANZ Management Research

Scarfe's 2008 thesis, Sustainable Management of Surfing Breaks, draws some parallels with this work. The thesis included assessments of surf break impacts and plausible management approaches and options based on physical processes and surfing performance. The work of Scarfe (2008) has a focus on quality data collection, particularly bathymetry, to identify key functional components. A large portion of the thesis is dedicated to a Multi-Purpose Reef (MPR) constructed at Tay Street in the Bay of Plenty. The overarching theme though is the requirement for ongoing monitoring. Much of the relevant findings of Scarfe (2008), and also the thinking of ANZ's leading surf science and management researchers at the time, is contained in Scarfe *et al.*, (2009c): Sustainable Management of Surfing Breaks: Case Studies and Recommendations. Relevant case studies include Manu Bay Boat Ramp (ANZ); Mission Bay Jetties (USA); Main Beach, Mount Maunganui (ANZ); Aramoana (ANZ), and Whangamata Bar (ANZ). The case study recommendations are slightly reticent, and again, largely point toward the requirement for more research and better monitoring. However, the work comprehensively presents details of the types of activities that can impact surf breaks, and the types of physical processes, and datasets, that are required to effectively evaluate the potential for impacts. The work of Scarfe *et al* (2009c) aligned with the revision of the NZCPS, and the recommendations that surf breaks be included in Environmental Impact Assessments and incorporate 'biophysical bottom lines' have since been realised in some cases. Furthermore, Scarfe *et al* (2009c) advocated a proactive approach with strategic environmental assessments. This too was essentially realised in the NZCPS, to date though there are still subnational authorities that are yet to incorporate surf breaks into policy instruments.

Scarfe *et al* (2009a) proposed an Environmental Impact Assessment checklist for surf breaks. The checklist aimed to help planners better understand the surf break functionality and mechanisms. Scarfe *et al.*'s (2009a) list of the factors included: bathymetry, wave climate, sediment transport pathways and grain sizes within littoral cell, wave refraction, peel angles, breaking intensity, surfer numbers, seasonal variations, the precise location of surfing rides, tidal patterns and long-term water level trends, wind patterns, relating surf break to surfer skill level, storm surge, surfable days per year, and, wave and tide induced current patterns.

Edwards (2013) undertook surveys and interviews with stakeholders to understand how user groups perceive the management of surf breaks and what they considered the associated values. The work suggests that management approaches need to include local stakeholders. In ANZ a community-driven approach is promoted in many elements of coastal management, particularly in the field of coastal hazards (e.g., Ministry for the Environment, 2017). Unsurprisingly, a key value of surf break users was wave quality, however, value attributes such as naturalness were also notable. Edwards (2013) recommends a co-management model whereby local communities are enabled to play a role in the identification, policy provision and monitoring of surf breaks. As previously mentioned, this type of community engagement is already practised in ANZ and, as Edwards (2013) points out, surfers are often a significant source of information for management purposes. While Edwards' (2013) options for co-management and the involvement of communities have value, it doesn't address the lack of awareness and expertise within governing authorities. A shortcoming in the approach is the lack of inclusion of surf break management and/or surf science experts; which would likely be required in the interpretation of stakeholder experience and knowledge into technical and policy terminology.

Skellern *et al* (2013) undertook a comprehensive study of various planning approaches to surf breaks and included physical and cultural aspects. This work also recommended stakeholder participation to help recognise, maintain, and protect surf breaks; and advocated a precautionary, as per the NZCPS, and integrated approach. Skellern *et al.* (2013) noted that effective management is constrained by a lack of information and methodological guidance about the resources in question. Skellern *et al.* (2013) identified four major themes under which effective surf break management could be implemented: policy framework; technical knowledge; local and indigenous knowledge; and, effects on surf breaks; they also recommended that a monitoring and research agenda is required with priority given to surf breaks with existing threats impacting on their integrity.

Peryman and Orchard (2013) undertook community surveys and interviews with stakeholders in the Bay of Plenty and Gisborne regions to better understand the perspectives of coastal communities regarding surf breaks. The work of Peryman and Orchard (2013) was seminal in documenting the social, cultural, economic and environmental attribute values of surf breaks and in discussing the concept of Surf Breaks of Regional Significance. To date, a range of methods to identify surf breaks of regional significance have been implemented, these include:

consultation with stakeholders (e.g., Coombes and Scarfe 2010; McNeil and Coombes, 2012) through workshops (Peryman, 2011c), individual interviews (Atkin and Mead, 2017; Atkin *et al.*, 2015; Peryman, 2011a, 2011c;), the appointment of an expert panel (Northland Regional Council, 2016a, 2016b) and surveys (Orchard, 2017b; Peryman, 2011a, 2011c; Taranaki Regional Council, 2017). Development of the SBRS concept, the methods used, and the latest interpretation of attribute values are discussed in Orchard *et al.*, (2019; Appendix B).

In some regions, alongside the identification of surf breaks of regional significance has been the construction and mapping of swell corridors. Methods for constructing swell corridors are limited to the grey literature of technical reports (Atkin and Mead, 2017; Atkin *et al.*, 2015; Atkin *et al.*, 2021). A first attempt at mapping swell corridors for the Auckland and Waikato regions was undertaken in 2012. Atkin *et al* (2015) and Atkin and Mead (2017) used numerical modelling of idealised wave conditions, validated against long-term met-ocean hindcasts, to compile a catalogue of incident wave paths for a range of surf breaks in the Greater Wellington Region and Waikato, respectively. For each surf break the wave path catalogues were used to determine footprints for swell corridors. The swell corridors were provided to the regional authorities for use in planning and decision-making.

Outside of ANZ, the swell corridor has been delimited by great circle paths (Ewans, 2002), which at the regional scale would essentially be straight lines. Other estimations of the extent of a swell corridor are based on the sources of swell and, sometimes, the alongshore limits of the surfing area, generally using a linear approach, some approaches simply state the compass direction the surf break is exposed to. The large-scale approach is interesting, particularly with respect to the generation source and the resulting surfing waves experienced, however, there is little value from a day-to-day management perspective. The importance of defining a surf break's swell corridor has been previously discussed (Nelsen *et al.*, 2013; Scarfe *et al.*, 2009a; 2009c) and is evidenced by its inclusion in the NZCPS.

2.4 International Context

Since 2001, but only enacted in 2013, Peru has had the Ley de Rompientes, surf break-specific legislation at the federal level, which identifies surf breaks as state property. Monteferri *et al.* (2013) provide a comprehensive overview of the Peruvian system. The National Registry of Rompientes is administered by the Peruvian Navy. The National Surfing Federation apply to the Peruvian Navy for a surf break to be included in the register. The application must include the name of the surf break, its location, geographic position and universal coordinates, a map of the area(s) to be protected, a descriptive technical profile and bathymetry studies that justify the existence of a surf break and that it is appropriate for surfing and related sports.

Activities that may impact the surf breaks, up to 1 kilometre along the coast on either side of the registered area, are also managed. In 2019, 33 surf breaks had been registered. Monteferri *et al.* (2013) note that Peru lacks marine spatial planning processes and that having a surf break specific legislative framework can reduce the threats (manage the resource) but may not prevent all impacts.

The Bells Beach Surfing Recreation Reserve in Victoria, Australia, was designated in 1973 and protects the subaerial coastal margin adjacent to the world-class surf breaks of Bells and Winkipop. The Bells Beach Surfing Reserve Coastal Management Plan (Surf Coast Shire, 2015) is prepared under the Coastal Management Act 1995 and the Victorian Coastal Strategy 2008 (Skellern *et al.*, 2013). Development of the plan was community-driven and informed using questionnaires and workshops, and recognises a range of values associated with the surf break. The management plan covers social, cultural, economic and environmental issues and presents action plans for each component, along with monitoring, elevation and reporting sections; the latter consists of two paragraphs with no technical components. The only other mention of monitoring is regarding the geotechnical stability of the cliff sections of the coast. There is no description of the functionality of the surf breaks and the processes and mechanisms that make them rideable. One notable inclusion in the plan is the acknowledgement of the potential effects of sea level rise and how the reef breaks of Bells and Winkipop may be affected.

National Surfing Reserves (NSRs; Farmer and Short, 2007) in Australia have been organised since 2006 and as of 2022, there are 22[4] NSRs. Similar to NSRs, and developed in part by the same founding individuals, are World Surfing Reserves (WSRs). Ware *et al* (2017) describe the Gold Coast World Surfing Reserve as a '*solution in search of a problem*' (page 115). While the rationale behind the dedication of NSRs and WSRs is one of protection, neither have direct links to federal, state or local policy instruments. They do however provide recognition of the resources, which is more likely to trigger management action. Ware *et al* (2017) describe it as a political foothold. There is no evidence of dedicated management strategies for the NSRs, however, the administrators of the WSR program, Save the Waves Coalition, have included evidence/methodology for the development of a reserve management strategy in the prerequisites for nomination. There are no generic management steps promoted by Save the Waves, but inclusion in policy is promoted as part of any long-term plan.

The City of Gold Coast (2015) commissioned the Gold Coast Surf Management Plan (GCSMP). The plan is very descriptive of the environmental setting, and inclusive of many

[4] Oz Beaches: National Surfing Reserves

attributes associated with surf break management, but low in technical detail. The coastal monitoring section includes the collection of wave, hydrographic and photographic data. The hydrographic survey plan described is very low resolution. Survey lines are separated by 400 m, which is too large to capture the full range of mesoscale functional components of surf breaks (Mead and Black, 2001a, 2001b). This survey type is more akin to a long-term beach monitoring strategy and was likely adopted from the GCSMP's predecessors, the Ocean Beaches Strategy and the Gold Coast Shoreline Management Plan. The two streams of coastal imaging, oblique and aerial, are both focused on shoreline position as a proxy for beach health and make no mention of surfing amenity. The final piece of the GCSMP is presented as key actions, some of which are directed at investigations to better understand surfing amenity on the Gold Coast.

Martin and Assenov (2014) presented a Surf Resource Sustainability Index (SRSI), focused on surf tourism in Thailand. The indicators are split into individual SRSIs for societal, economic, environmental and governance components. While not the specific aim of Martin and Assenov's (2014), the SRSI components (Table 2.1) resonate with the management of surf breaks.

Table 2.1: SRSI components of Martin and Assenov (2014).

Societal	**Economic**	**Environmental**	**Governance**
Clubs - Boardriders	Surf Amenity and Infrastructure	Biodiversity	Beach and Water Safety
Clubs - Lifesaving	Surf Events	Coastal Engineering	Education and Interpretation
History	Surf Industry and Commercial Activity	Eco-Physical Carrying Capacity	Legislative Status
Public Safety	Surf-Related Nonmarket Values	Hazards - Marine Life	Management
Social Experience	Surf Tourism	Hazards - Physical	Not-for-Profit Organizations
Socio-Psychological Carrying Capacity		Quality - Beach	Public Access
Surf Community		Quality - Water	
Surf Events		Surf Type and Quality	

Reiblich (2013) argues that having a narrow definition of a surf break limits the mechanisms for protection and that three zones need to be considered when looking to protect a surf break: '*the submerged lands under the wave zone, a wave corridor which allows an unimpeded right of way for swells to reach the wave zone, and beach access*'. Reiblich (2013) discusses the pros and cons of using Marine Protected Areas (MPAs), World Heritage Sites, National Park designations and the National Register of Historic Places to protect surf breaks in the United States, but does not go as far as to recommend any particular management strategies, beyond acknowledging the swell corridor, the seabed in the area of surfing, and access.

Ball's (2015) work is focused on the protection of surf breaks and looks at mechanisms in the United States, with reference to global examples. Some of the mechanisms are focused on a legislative approach and others fall into the category of unsanctioned recognitions. In terms of actual management strategy, Ball (2015) recommends a 'hands off approach', but at the same time that any proposed activity should be planned to preserve natural processes. No implementable steps for effective management are proposed.

2.5 Summary

ANZ has pioneered innovative approaches to surf break management and is one of very few countries that acknowledges surf breaks as coastal resources within legislation. This acknowledgement in ANZ is primarily in the form of Policy 16 of the NZCPS, the glossary of which includes the concept of a swell corridor providing a clear indication that the functionality of surf breaks extends well beyond the immediate area of participation. Despite the legislative framework in ANZ, the list of issues associated with impacts on surf break's is long and ongoing. Policy 3 of the NZCPS directs a precautionary approach, particularly when there is an absence of understanding, which has been a common theme in surf break management cases. The absence of understanding often stems from a lack of data on existing surf break characteristics, but also a lack of consistency in management approached and expertise. Variety in the implementation of the Surf Breaks of Regional Significance concept across ANZ's regions exemplify this. Quantified baselines of surf break's anywhere across the planet are very rare. The isolated examples of surf break management are generally analytical and inconsistent, lacking a holistic approach.

3 Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance

Publication details:

Atkin, E.A., Mead, S.T., Bryan, K., Hume, T. and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. In Proceedings of the 23rd Australasian Coasts and Ports Conference – Cairns, Australia, 21-23 June 2017, p. 13-19.

 Pagination is not included in the reproduced article, page references to any errata are relevant to the main body of this thesis.

This chapter provides an introduction to the overarching Ministry for Business, Innovation and Employment (MBIE) research project. The paper describes the methods used and presents the findings of the research up to that point in time (2017). Publication constraints limited the amount of detail in the paper, therefore additional information is provided here.

A steering group was established to ensure the project achieved its goals and that relevant stakeholders were genuinely involved. The Guidelines were developed under guidance of the steering group, which included representation from: Auckland Council; Department of Conservation; Landcare Research; Lincoln University; Waikato Regional Council; Surfbreak Protection Society; and, Surf Life Saving New Zealand.

The numbered list of project components (pg. 2) was abridged to six components for the purpose of the paper, instead of using the seven original research components: 1) study site selection; 2) scoping studies and stakeholder workshops; 3) geomorphological and surf break assessment; 4) data collection; 5) detailed analysis; 6) development of a website and online portal; 7) the development of management guidelines.

Study site selection was undertaken during the MBIE project proposal development stage. The proposal had to consider temporal and budgetary constraints when selecting the number of study sites for this project. A determined prerequisite for the list of selected study sites was that collectively they were representative of the different surf break types found across ANZ.

Remote sensing systems at two Surf Break of National Significance were established prior to the initiation of the MBIE research project. These were Aramoana and Whareakeake in Otago. An agreement that the image data from the camera stations monitoring Aramoana and Whareakeake would be made available for use in the research project, making these sites an automatic inclusion in the set of study sites.

A decision-making matrix to determine which other surf breaks to include in the study was constructed. The scoring categories of the matrix included: access, infrastructure, environment sensitivity, threats, usage, dependent population, Surf Life Saving New Zealand presence, and effectiveness of remote monitoring methods. The 17 Surf Breaks of National Significance and 5 other Surf Breaks of Regional Significance that have notable public interest (Lyall Bay, Piha, Matakana Island, Main Beach Tauranga, and Fitzroy) were evaluated using the matrix.

The 6 highest scoring surf breaks in the matrix, from highest to lowest, were Whangamata Bar, Manu Bay, Lyall Bay, Whale Bay, Piha and Wainui Beach. With the interest of ensuring that the chosen sites were representative of surf breaks across ANZ, and collating as much useful data for a given budget, Whale Bay was excluded from the study, the reason being that Manu Bay and Whale Bay are both exposed west coast boulder/rock point breaks. This short list of 5 along with Aramoana and Whareakeake, which ranked 12th and 10th in the matrix, respectively, made a total of seven surf breaks across ANZ.

Stakeholder recruitment leveraged the network of Boardrider Clubs in ANZ, social media platforms, a dedicated project website, and more traditional newspaper advertisements. Boardrider Club rooms, Surf Life Saving New Zealand facilities, or other central, community/public buildings, were utilised to host the events on Saturday afternoons (1400-1600). An important step prior to the stakeholder meetings involved consultation with tangata whenua (local Māori, people of the land) who have kaitiakitanga (guardianship) of each area in order to seek approval for conducting research within their rohe (tribal boundaries), ensure that the research aims and methods aligned with the local Iwi's values and beliefs and to determine how each surf break is valued and used by Iwi. To this end, local iwi were identified and contacted by the MBIE project's cultural lead, Dr Jordan Waiti. Prior to stakeholder engagement Iwi were contacted and visited in person to gauge their interest in the project, obtain local knowledge, provide the opportunity to raise any concerns in relation to the project. A specific question put to Iwi representatives was their support for the project and the permission to install a video monitoring system (Appendix D). Stakeholder engagement provided a platform and encouraged discussion on observations of the coastal/surfing environment including any threats and changes, and the cultural and historical significance of sites. The information recording during stakeholder engagement was not quantitatively analysed. The information was used to inform the development of the qualitative surf break characterisation of each study site (Appendix D). Stakeholder engagement also facilitated the identification of local surfers as suitable candidates to receive a GPS tracking watch to assist in the establishment of a baseline dataset.

This chapter and the work associated with it largely shaped the content of the Guidelines, and provided context for the subsequent chapters of this thesis.

Chapter Errata

Cor – correction of language

Page/Line	Original text	(type of correction) Corrected text
36	"… video imagery (Figure 3-A)."	(Cor) "… video imagery (Figure 3; left)."
36	"… seabed features (Figure 3-B)."	(Cor) "… seabed features (Figure 3; right)."
39	"… distinct feature (left side)."	(Cor) "… distinct feature (right side)."

Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance

Ed Atkin[1], Terry Hume[2], Shaw Mead[1], Karin Bryan[3], and Jordan Waiti[4]
[1]eCoast, Raglan, New Zealand
email: e.atkin@ecoast.co.nz
[2]Hume Consulting Ltd, Hamilton, New Zealand
[3]University of Waikato, Hamilton, New Zealand
[4]Māori Health and Development, Raglan, New Zealand

Abstract
The objective of this 3-year Ministry of Business, Innovation and Employment funded research project is to build a knowledge base and to develop management guidelines for New Zealand's nationally and regionally significant surf breaks. Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS) provides a legislative framework that identifies and calls for the protection of surf breaks of national and regional significance by "ensuring that activities in the coastal environment do not adversely affect the surf breaks" and by "avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks". While this is ground-breaking as the world's first environmental policy to specifically identify surf breaks as protected spaces, it is somewhat toothless in its effectiveness because there are no clear, quantitative measures or guidelines describing the oceanographic or geomorphic characteristics of the coastal zone that contribute to the functionality of a surf break. This research is addressing a fundamental issue that there is little information or understanding of surf breaks to enable informed decision-making by council staff, engineers and consultants about activities in coastal areas that encompass or influence the functionality of New Zealand's surf breaks. This paper describes how the research will fill the current information gap and how it is being accomplished by establishing a network of remote sensing monitoring stations at selected surf breaks, field data collection, numerical modeling, undertaking detailed analysis of new observations and data (including GPS surfer-tracking), incorporating existing knowledge and feedback from end users and stakeholders via workshops, using the information to develop guidelines for resource management, and finally making a database and findings freely accessible through an online data portal.

Keywords: coastal monitoring, resource management, surf break, surfing, guidelines.

1. Introduction

In 2014 tourists contributed $10.3 billion dollars to New Zealand's economy, making up 4% of the country's GDP [14]. Of the nature-based tourism activities, visiting beaches is by far the most popular [13]. Assuring that natural capital is preserved is critical for ongoing growth. In 2015 more people participate in surfing in New Zealand than play rugby [19].

New Zealand has many high quality and socioeconomically important surf breaks frequented by a large wave riding community of both domestic and tourist origin. The realisation that these surf breaks are coastal resources and that the integrity of some surf breaks can be threatened by coastal activities led to the classification of 17 "Surf Breaks of National Significance" in the New Zealand Coastal Policy Statement 2010 (NZCPS). The purpose of Policy 16 of the NZCPS is to: *"Protect the surf breaks of national significance […], by:*
(a) Ensuring that activities in the coastal environment do not adversely affect the surf breaks, and;
(b) Avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks"

There is a requirement in sustainable and adaptive management to have a clear and holistic understanding of the physical environment and the ecosystems that occupy them. At present there is little to no data pertaining to the existing wave quality, breaking patterns, physical drivers, and the socioeconomic importance of New Zealand's surf breaks. Without this information, predicting and assessing the consequences of coastal activities on the surf breaks, and, moreover, developing realistic and defensible guidelines for their protection is extremely difficult. This leaves resource managers struggling to give effect to the Resource Management Act 1991 and effectively uphold the intent of the NZCPS. In the past this lack of understanding has led to discords between community groups and coastal industry; and any much needed action in this respect.

This paper introduces and details methodologies and preliminary findings of a project funded by New Zealand's Ministry for Business, Innovation and Employment. The primary aims of the project are to build a knowledge base, establish baseline data and develop management guidelines for New Zealand's surf breaks. The project is entitled: Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional

Significance. The project is comprised of the following components:
1) Study site selection
2) Collation of local and existing knowledge
3) Physical data collection
4) Data Analysis
5) Dissemination of data
6) Development of guidelines.

2. Project Methods

To date, the 36-month project is 17 months in. Components 1 and 2 have been completed in full. Components 3 through 7 have all been initiated. The following provides details on each of these components.

2.1 Study Sites

A total of 7 seven sites are being studied in the project. The surf breaks of Aramoana and Whareakeake in Otago (Figure 1) met certain criteria and were being monitored prior to the start of this project and were therefore included. In choosing further sites the 17 Nationally Significant Surf Breaks and other Regionally Significant Surf Breaks of public-interest (Lyall Bay, Piha, Matakana Island, Main Beach Tauranga, and Fitzroy) were evaluated using a decision-making matrix. The scoring categories of the matrix were: access, infrastructure, environment sensitivity, threats, usage, dependent population, SLSNZ presence, and effectiveness of remote monitoring methods.

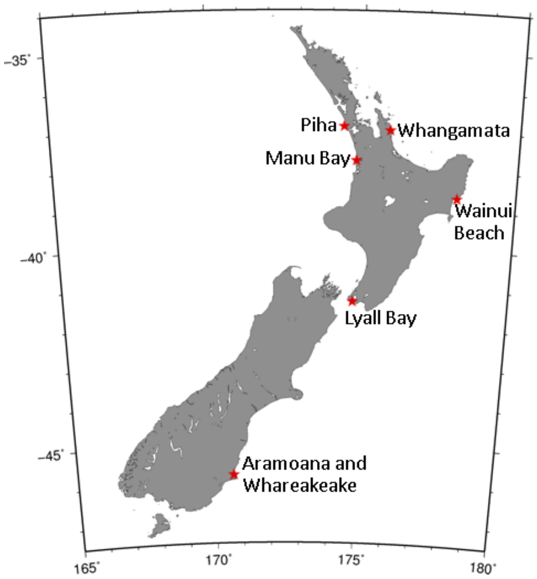


Figure 1. Map of New Zealand showing the location of the seven study sites.

The 6 highest scoring surf breaks in the matrix, from highest to lowest, were Whangamata Bar, Manu Bay, Lyall Bay, Whale Bay, Piha and Wainui Beach. With the interest of ensuring that the chosen sites were representative of surf breaks across New Zealand, and collating as much useful data within budgetary constraints of the project, Whale Bay was excluded from the study. The rationale being that Manu Bay and Whale Bay are both exposed, west coast, boulder/rock point breaks within 1 km of each other.

Piha, Whangamata, Manu Bay, Wainui Beach, Lyall Bay, Aramoana and Whareakeake (Figure1) are representative of the different types of surf breaks [11] found within New Zealand.

2.2 Collation of local and existing knowledge

This process included advertised stakeholder meetings at each of the study sites and surveys (analogue and online); which encouraged participation from local and non-local, surfer and non-surfer, business owners, Māori and Pākehā alike. Stakeholder engagement included respectful, meaningful engagement and consultation with tangata whenua (local Māori, people of the land) who have kaitiakitanga (guardianship) of each area.

Stakeholder workshops operated in 3 stages. The first stage was based around 3 to 4 “stations” with aerial photographs of the relevant study site spread out on tables available for discussion and annotation. Secondly, a presentation summarised the project’s aims and methodology. Following this, an open floor discussion took place.

Initial geomorphological assessments were undertaken during site visits and combined with a desktop exercise to collate all existing data pertaining to surf break functionality, from local geomorphology to coastal care practise. This component included literature reviews of scientific journal articles, community group websites, technical reports, and other published material.

2.3 Physical Data Collection

The primary data collection methods used in this project are: Remote video imaging systems; hydrographic surveys; and Geographical Positioning System (GPS) data of surfers whilst riding waves.

2.3.1 Imagery

Each study site will have a video imaging system installed (e.g [4]), which will be used to assess seabed and breaking wave characteristics. Aramoana and Whareakeake surf breaks have monitoring systems established prior to the initialisation of this study (Figure 2), hence the automatic inclusions of these sites.

The systems established as part of this project will acquire 1,200 images each hour during day light, every day, all year round. Following collection of the 1200 mages, the stack, or “image cube” is automatically processed to extract an average, standard deviation and variance image. These outputs, along with 20-30 consecutive of still images are uploaded to a cloud-based server. Apart from 1 image cube collected each day, which is stored locally, the image cubes are discarded post processing.

Figure 2. Camera monitoring system installed at Whareakeake at the top of the valley looking down on the surf break along the headland (left image, right hand side).

At each site, Geographical Control Points (GCPs) are collected using a Real Time Kinematic (RTK) Geographical Positioning System (GPS) in the camera's field of view allow for geo-referencing of each pixel within a given image. These georeferenced pixels are used to convert the image to a birds-eye view (ortho-rectified; Figure 3).

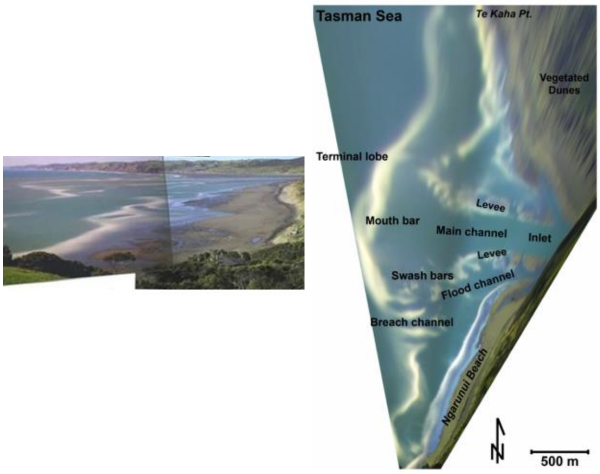


Figure 3. The time-average image (left) taken from NIWA cameras of Ngarunui Beach (Raglan, New Zealand) and georectified image and annotated (right) [9].

2.3.2 Bathymetry

Sea floor topography, or bathymetry, of the surf break and the surrounding area is collected during hydrographic surveys, where depths and positions (RTK-GPS) are collected synchronously. To capture changes in seabed topography over time, surveys will be repeated throughout the study period.

2.3.3 Surfer Position

As part of an ongoing research project established between eCoast and Rip Curl, 3 SearchGPS watches were donated to competent, local surfers at each of the 7 sites during stakeholder engagement. The watches worn by surfers have an internal GPS that track a surfer's position during a surf and each time they catch a wave. This data is uploaded from the watch to a cloud based server; which provides positions at a rate of 1 Hz (Figure 4).

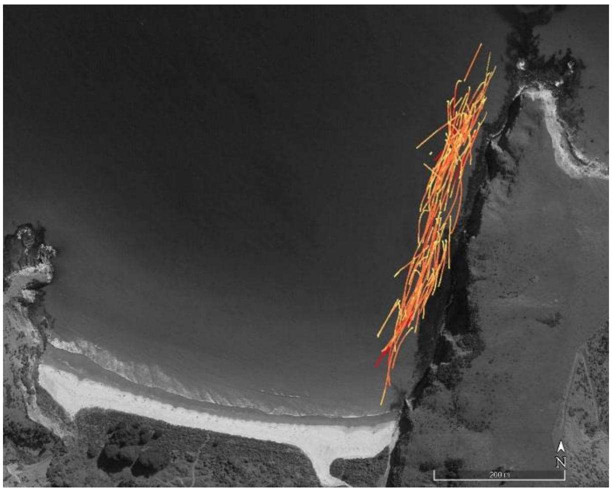


Figure 4. Surf tracks overlaid on a Google Earth image taken of Whareakeake surf break, Otago.

2.4 Data Analysis Methods

2.4.1 Imagery

From the geo-rectified images provided by the onshore video cameras, features are measured to a high degree of accuracy. Colour and intensity variations in the georectified images are processed to extract shoreline [5], rip current [7], sandbar [20], and wave propagation [8] characteristics.

Seabed morphology can be identified by averaging video imagery (Figure 3-A). Averaging the video imagery removes the light intensity variations created by random wave breaking patterns providing a clear representation of seabed features (Figure 3-B). This technique has been verified to represent true bathymetry by a range of studies [10].

One of the main parameters for evaluating surfing wave quality is wave peel angle, which is defined as the angle between the path of the wave break point and crest of the unbroken wave [6, 21]. New analysis techniques, specific to surfing and surf break quality, are being developed as part of this project based on existing analysis techniques [7] to allow peel angles to be assessed from geo-rectified images.

2.4.2 Bathymetry

The catalogue of bathymetric data from each of the 7 sites is used to construct numerical models with which wave propagation and breaking are simulated. The model output is post processed to determine wave breaking intensity [12]. The vortex ratio of a breaking wave describes the shape of a plunging breaker by evaluating the length and width of the wave's vortex – the open part of a breaking when viewed side on [12, 16]. The extracted peel angles (imagery) and breaking intensities will be used in wave quality assessments to establish statistical thresholds for surfing at a given break.

2.4.3 Surfer Position

The global dataset available from the SearchGPS watch is remarkable and provides a resource to determine many aspects of surf break [3], including a surf break's functional performance. The positional data allows determination of physical parameters such as surfer speed and ride length, but also geographic parameters such as surf break areas [2], take off zones, access routes etc. The surfer GPS data will also be used to validate numerical model outputs. Overlays of raw and/or post processed data on model output allows a heuristic but effective evaluation of whether the numerical schemes are replicate the real life physical process.

2.5 Dissemination of Data

The data collected in this research will be made publicly available through a website and online portal providing the opportunity for other organisations, including universities and crown research institutes, district and regional councils, port and harbour authorities, marine resource prospectors and coastal developers to use the data for their own research, consent applications and/or planning purposes. The website will provide background information on the research project, include all the technical reports and present the findings of the project.

2.6 Development of Guidelines

The knowledge gained from this research will aid in the development of guidelines for the sustainable management of surf breaks. Our work will translate measurable scientific parameters into clear guidelines that can be implemented by practitioners ranging from engineers to planners and community groups. The guidelines will include, but not limited to, the methodology for quantifying surf breaks, methodology for establishing tolerance levels, assessing potential threats and mitigation options, minimum requirements for data collection during a study, and case studies for the 7 study sites.

3. Results

Stakeholder engagement and data collection to date show the following:

3.1 Piha (South)

Piha stakeholders value the beach environment greatly viewing it as a global attraction, and are aware of Piha's national and international recognition as a venue for many surfing contests, and the quality of the wave, the latter being "crucial to defining surfing as a sport in New Zealand".

Stakeholders are also very aware of the dynamic nature of this west coast beach, noting it changes every day. Some note its proximity to Auckland as an important factor, indeed, this break was included by scoring highly in the "Dependent Population" category of the study site decision making matrix.

Piha is credited with being the birthplace of the modern surfing movement in New Zealand. While wave riding was undertaken previously, the sport in New Zealand evolved in 1958 when two US lifeguards, Rick Stoner and Bing Copeland, brought malibu boards to Piha. The waves at Piha can be very powerful and hollow. There are multiple breaks in the bay that, like many of New Zealand's exposed west coast breaks, are largely dependent on sediment and sand bank movement, which in turn are a function of incident wave climate and the streams that discharge on to the beach.

Current threats to the surf break at South Piha are perceived as coming from: 1) an increased influx of sand into the bay and changing the configuration of rip channels and sand banks offshore and 2) sand being locked up in the dunes and unavailable to form sand banks offshore.

Locals see a threat to the surf breaks at Piha as being dune conservation works (shaping and planting) to combat coastal erosion. It is perceived by some that while the sand is locked up in the dunes it is no longer available to build the sand banks offshore and therefore having a detrimental effect on the surfing conditions. A potential future perceived threat is plans for offshore seabed sand mining of iron sands.

3.2 Whangamata

"The Bar", that breaks over Whangamata Harbour's ebb tidal delta, is classified as an estuary bar break [11] or river/estuary entrance bar [17].

There is a long ongoing debate as to whether the quality surf break has been compromised by the development of a marina inside the harbour. There is insufficient data to determine cause and effect and the studies undertaken regarding resource consent [15, 18] provide little useful information with respect to actual impacts.

Periodic maintenance dredging is employed to ensure the channel retains a depth of ~1.5 m below Lowest Astronomical Tide. There is controversy with respect to the impacts of dredging the marina (both development and maintenance), and while there is some indication of morphological differences in the bar's overall shape pre/post-marina development [1], there is no evidence to determine whether these differences are natural or in any way connected to the marina development.

Further concerns raised during stakeholder consultation include wastewater treatment practice by the council with reports of spills and leakage of sewage waste from aeration ponds into the Whangamata Estuary; and stormwater discharge near the surf breaks.

3.3 Manu Bay

Manu Bay is the last in a succession of several left-hand point breaks that are comprised of volcanic (andesitic) boulders that fan out from above the high tide mark to form rocky/boulder reefs to depths of 3-6 m. From the toe of the reef, a sand platform extends offshore.

At the eastern end of Manu Bay, the presence of the boat ramp and breakwater, first built in the 1960s has caused a large scour hole on the structure's western side resulting from increased offshore-directed currents induced by wave setup between the breakwater and adjacent land, and wave reflections ("backwash") off the breakwater itself. The presence of the breakwater prevents the movement of boulders along the upper shore, leading to erosion on the eastern side of the boat ramp.

The structures interrupt the natural fan-shape of the boulder field some three quarters of the way from west to east. During construction, sub and intertidal substrates were excavated from a ~2,000 square metre area, creating a 50 m (approx.) wide gap in the pre-construction morphology (Figure 5; [17]).

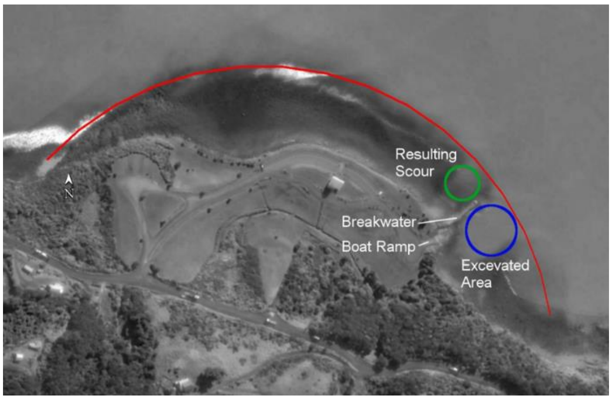


Figure 5 Annotated Google Earth image of Manu Bay.

Stakeholders indicated that there is significant value associated with the quality and consistency of the surf; they value the ease of access at Manu Bay, and that it is inclusive to surfers of all ages and abilities; it "provides the perfect stepping stone for intermediate surfers progressing from a "beach only" surfing experience". The local topography at Manu Bay also provides an excellent viewing spot to watch the surf. Manu Bay is considered the heart of a large surfing community which families have built their lives around.

Yet, some stakeholders feel that many surfers disrespect the tangata whenua. Waikato-Tainui Māori have a bi-annual surf competition held at Manu bay. It is open to all surfers who have whakapapa (ancertral relationships to) to Waikato-Tainui. This whānau-centric event is not necessarily a competition per se, but rather it focusses on whanaungatanga (togetherness), participation, reaffirming cultural ties, and celebrating Waikato-Tainui identity.

The biggest perceived threats to surfing amenity is not having the voice of the local surfers heard during decision making processes. There are concerns over the sharing of space with surfers and recreational boats occupying the area at the same time. Other observations included: septic or sewage spills occurring within the reserve, and major concerns about water quality and ecology of the area (with specific notes about the odour and colour of the water).

3.4 Wainui

Wainui is renowned for producing steep, powerful, hollow waves. There are multiple peaks located along Waiuni Beach This study is concerned with the break known as Pines, a reef break that intermittently becomes covered sand.

Stakeholders clearly indicated that the community have traditional history of ownership, use, and protection, and that currently the local council supports the natural setting. Dune care or coast care planting is also considered to assist surf breaks and not prevent offshore and alongshore sand movements, only increase the volume of sand along the shore.

Multiple stakeholders reported water quality issues associated with the Hamanatua Stream, that discharges onto the beach near Pines, attributing the issue to the catchment being largely comprised of farmland.

3.5 Lyall Bay

Lyall Bay is the New Zealand's most historic surfing venue where the Hawaiian Duke Kahanamoku (The Duke), a 5-time Olympic swimming medallist, introduced surfing to New Zealand in 1915. Stakeholders in Lyall Bay recognise that the surf break provides a valuable resource for economic, social and recreational growth; that surf breaks of real quality are rare; and note that accessibility to this inner-city break makes it unique.

Lyall Bay is bound to the east by Wellington airport's runway (Figure 6). In 2015, plans to extend the runway by 350 m were announced. This is the primary threat to the surf breaks as identified by stakeholders, followed closely by coastal erosion.

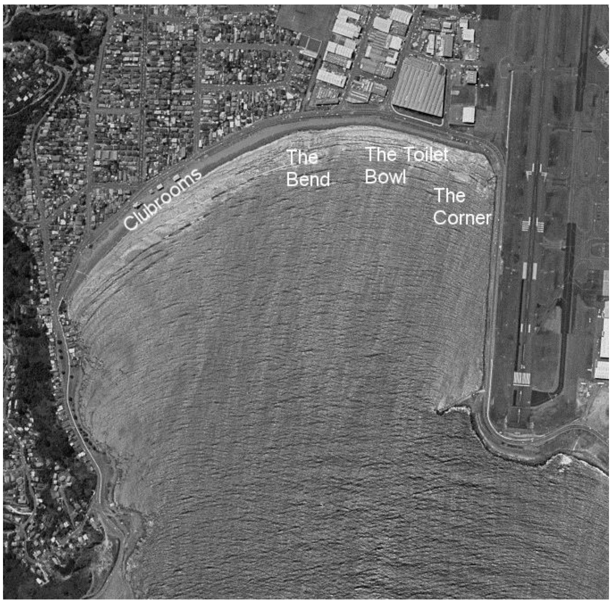


Figure 6. Aerial photograph of Lyall Bay annotated with the recognised surf breaks (white text). The runway is a distinct feature (left side).

Initial impact studies of the extension have indicated that the surfability of waves will be decreased by the extension. This is caused by a reduction in wave 'peakiness' due to the extension, which will have a consequent reduction on the number of surfable waves. In addition, the surf break called "Airport Rights", located at the end of the runway, will be lost due to being covered by the airport extension. It has been proposed that a 'focus' reef be constructed in the middle of the bay to mitigate the loss of surfing amenity.

Additional threats to "The Corner" surf break at Lyall Bay include ongoing modifications to the airport reclamation. Anecdotal evidence indicates that the reduced reflectivity of the reclamation has been detrimental to wave quality. A beach carpark extension is also perceived to have a negative impact.

3.6 Aramoana

The surf break of Aramoana, or "The Spit", is complex as it relies on a two-phase preconditioning process to make it function at a level warranting its Nationally Significant status. Waves incident to The Spit focus on the terminal lobe of the Ebb Tidal Delta (ETD) adjacent to the entrance of Otago Harbour. This focusing create a localised band of increased wave heights, realigning wave crests and setting up longshore wave height gradients. The band of increased wave height is generally focused central to Aramoana Beach. Inshore of the ETD, a dredge disposal site has been used since the 1980s to dispose of spoil and created a mound. The inshore spoil ground acts to focus and bifurcate waves, but to a lesser degree than the ETD. The result is the classic, peaky A-Frames of Aramoana.

Stakeholder information indicates that surfing conditions were very good during initial disposal of dredge material. By the early 21st century wave quality was diminishing with further disposal. A proposal to greatly increase the volume of sand to be dumped at the Aramoana was met by opposition. Settlement was agreed out of court to obtain a 3-year temporary permit with greatly reduced disposal at the nearshore site. No dredge material was placed at Aramoana for the first 2 years, during which time it was perceived by all parties involved that surfing conditions had improved. During this time the breaks have been monitored with camera systems like those being established as part of this project. These systems will be imperative in monitoring and managing this anthropogenically modified surf break.

3.7 Whareakeake

Whareakeake is located some 5 km northwest from the entrance to Otago Harbour. Offshore from Whareakeake is a dredge spoil disposal site (Heyward's), which has been in operation for over a century.

During a temporary resource consent studies helped to determine how the orientation and shape of the disposal mound impacted on waves incident to Whareakeake. This has led to a large increase in the size of the disposal ground to enable better management in terms of mound orientation and mound height. Like Aramoana, continued monitoring is required to ensure that the management of the morphology of the Heyward disposal mound does not negatively impact on Whareakeake.

Māori organisations have worked closely alongside Port Otago in regards to the port dredging, and are supportive of the dredging, subject to various conditions, such as maintaining and improving monitoring.

4. Summary

There have been no substantial quantitative assessments undertaken at these study sites, except for Manu Bay. Considerable qualitative data was collected from the open feedback sessions, from surveys (both analogue and online), and desktop studies. The key perceived and/or potential threats appear to be development and water quality. Natural threats were also evident at sandy beach sites. Whilst some threats are common to the breaks, each site has specific issues or variations of the common theme. Differentiating between natural and anthropogenic effects is a clear challenge for the project.

Appropriately seeking approval to conduct research within specific rohe (tribal boundaries), and a desire to ensure that the research aims and methods align with local Iwi's values has also been very well received. Without endorsement from local stakeholders this project would not be possible.

The existence and quality of the surf breaks being investigated formed an essential part of the local culture, both for Māori and non-Māori and for the visitor and tourist experience, and re-enforces the vital essence of the importance of this body of research work to New Zealand and its people.

The benefits of this projects transcend New Zealand with direct access to the data and all processing components being made available. This will provide further opportunities for a range of purposes, both in and outside of New Zealand, including post-graduate research, resource management examples and sustainable development purposes. This research will culminate in guidelines that will enable science-based informed decision-making by council staff, engineers and consultants about activities in coastal areas that have the potential to threaten the functionality of New Zealand's surf breaks; and therefore, support the sustainable management of coastal resources.

5. Acknowledgments

The research team would like to thank: New Zealand's Ministry of Business Innovation and Employment; the project steering committee, containing representation from the Department of Conservation, Landcare Research, Surfbreak Protection Society, Surf Life Saving New Zealand, Waikato Regional Council, Auckland Council, and Lincoln University, all stakeholders for their input; and, Rip Curl for their donation of 21 SearchGPS watches.

6. References

[1] Atkin, E. A. Greer, S. D. and Pickett, V. (2013) Whangamata ebb tidal delta morphology and wave breaking patterns. Coasts and Ports 2013: 18-22.

[2] Atkin, E. A. and Mead. S. T. (2016). Regionally Significant Surf Breaks in the Waikato Region. eCoast technical report prepared for Greater Wellington Regional Council.

[3] Borrero, J., Bouard, T., Atkin, E. A., Mead, S. T., and Helm, S. (2016). Use of Rip Curl Search GPS watch data for the mapping, monitoring and analysis of surf breaks. New Zealand Coastal Society 2016.

[4] Bryan, K.R., Hume, T.M. and Payne, G., (2000). The Cam-Era Final Report, prepared for The Ministry for the Environment, NIWA Client Report, MFE00212, 29pp.

[5] Bryan, K. R., Foster, R. and MacDonald, I., (2013). Beach rotation at two adjacent headland enclosed beaches, Journal of Coastal Research, Special Issue 65, 2095-2100.

[6] Dally, W. R., (1989). Quantifying Beach 'Surfability'. Proceedings, Beach Technology Conference, Tamp, Florida, February 1989.

[7] Gallop, S. L., Bryan, K. R., Coco, G., Stephens, S. A., (2011). Storm-driven changes in rip channel patterns on an embayed beach. Geomorphology, 127(3-4), 179-188.

[8] Guedes, R.M.C., Bryan, K. R., and Coco, G., (2012). Observations of alongshore variability of swash motions on an intermediate beach, Continental Shelf Research, 48, 61-74.

[9] Harrison, S. R. (2015). Morphodynamics of Ebb-Tidal Deltas. Doctor of Philosophy thesis, University of Waikato, NZ (unpublished). pp 176.

[10] Lippmann, T. C and Holman, R. A., (1989). Quantification of sand bar morphology: A video technique based on wave dissipation. Journal of Geophysical Research 94.

[11] Mead, S. T., (2000). Incorporating High-Quality Surf breaks into Multi-Purpose Reefs. Doctor of Philosophy in Earth Sciences. University of Waikato. pp 209.

[12] Mead, S. T. and Black, K. P., (2001c). Predicting the Breaking Intensity of Surfing Waves. Special Issue of the Journal of Coastal Research on Surfing 51-65.

[13] Ministry of Business, Innovation and Employment. (2009). Tourist activity, nature-based tourism New Zealand, series b3, August 2009.

[14] Ministry of Business, Innovation and Employment. (2015). Annual Report 2014/2015.

[15] Pearce, G. (2013). Whangamata Ebb Tidal Bar, Monitoring Report. Tonkin and Taylor report prepared for Whangamata Marina Society.

[16] Sayce, A. (1997). Transformation of Surfing Waves Over Steep and Complex Reefs. Unpublished Thesis, University of Waikato, New Zealand.

[17] Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T. (2009). Sustainable Management of Surfing Breaks: Case Studies and Recommendations. Journal of Coastal Research, 25(3), 684–703.

[18] Shand, T. (2008). Whangamata Marina Numerical Model Development and Reporting. Tonkin and Taylor report prepared for Whangamata Marina Society.

[19] Sport New Zealand (2015). Sport and Active Recreation in the Lives of New Zealand Adults. 2013/14 Active New Zealand Survey Results

[20] van der Lageweg, W. I., Bryan, K.R., Coco, G. and Ruessink, B. G. (2013). Observations of shoreline-sandbar coupling on an embayed beach, Marine Geology, 344, 101-114.

[21] Walker, J. R. (1974). Recreational Surf Parameters. LOOK Laboratory TR-30, University of Hawaii, Department of Ocean Engineering, Honolulu, Hawaii.

4 Management Guidelines for Surfing Resources

Publication details:

Atkin, E.A., Bryan, K., Mead, S.T., Hume, T. and Waiti, J., 2019. Management Guidelines for Surfing Resources. In Proceedings of the 24th Australasian Coasts and Ports Conference – Hobart, Australia, 10-13 September 2019, p. 42-48.

The publisher has been granted permission to reproduce this article in the published format. Pagination is not included in the reproduced article, page references to any errata are relevant to the main body of this thesis.

This chapter presents an abridged version of the Management Guidelines for Surfing Resources (Appendix A), with a focus on a novel risk assessment methodology. The chapter provides background on why the Guidelines were developed and outlines the structure of the document and the key takeaways for authorities, resource users and consent applicants (those wishing to undertake activities). The development of the Guidelines relied heavily on the authors experience and exposure to both coastal management guidance in the form of coastal hazard best practice and the litany of management issues related to surf breaks in both ANZ and overseas. Other reference points included erosion management guidelines and good practice guidelines under the Resource Management Act.

One of the major outcomes of this research was the definition of the term “Surfing Resource”. This is discussed further in Chapter 10. In summary, the term had not been commonly used in context in either an informal manner or within published works. Evolution of the term was necessitated by the inclusion of a description of a surf break in the New Zealand Coastal Policy Statement 2010 (NZCPS) which was firmly grounded in physical attributes and process. Surfing Resource acknowledges a range of value attributes beyond the physical components and processes, and is aligned with the terminology used in legislative and regulatory frameworks for managing other asset classes (e.g., fisheries and minerals).

This paper refers to the NZCPS term of surf break integrity, which relates to resource usage and functionality. The Resource Management Act (RMA) is an effects-based piece of legislation. In this paper the threats are considered as the projected effects on surf break integrity, resolved from detailed studies. If, for example, an activity was to construct a wall through a Surf Break Area (SBA), the functionality and usage would be compromised. Similarly, if the wall were constructed around the SBA, usage and access to the resource would be compromised.

The risk assessment developed as part of the Guidelines, on which this paper is focussed follows the standardised approach of defining the consequence of an activity (Catastrophic, Major, Significant, Minor) and the likely hood of impact (Highly Unlikely (Rare), Unlikely (Remote), Moderate (Occasional), Likely (Frequent), Very Likely (Permanent/ Frequent), while providing examples and definitions within the context of surfing resource management and the terminology used in the NZCPS. The list of potential activities that may impact on and the sources of surf break integrity, and the definitions/examples provided in the risk assessment where derived from both the literature review and the stakeholder engaged undertaken earlier in the research project.

Figure 2 in the paper presents the swell corridor, based on the Relative Percentage Activity (RPA), determined from the long-term wave climate, for Aramoana. The background to RPA and the development of swell corridors is provided in Chapter 6.

<u>Chapter Errata</u>

Cor – correction of language

Page/Line	Original text	(type of correction) Corrected text
45	"Figure 2. Relative Percentage Activity to construct the swell corridor for Whareakeake, with the Territorial Sea limit (red line) [1]."	(Cor) "Figure 2. Relative Percentage Activity (RPA) to construct the swell corridor for Whareakeake, with the Territorial Sea limit (red line) [1].
46	"Table 2. Potential activities/threats/sources of surf break integrity…"	(Cor) "Table 2. Potential activities, threats and/or sources of surf break integrity…"
48	"…escalation to environment court appeals, meditation and other legal and social conflicts"	(Cor) "…escalation to environment court appeals, mediation and other legal and social conflicts"

Management Guidelines for Surfing Resources

Ed Atkin[1,2], Karin Bryan[2], Shaw Mead[1], Terry Hume[3], and Jordan Waiti[2]
[1]eCoast, Raglan, New Zealand
email: e.atkin@ecoast.co.nz
[2]University of Waikato, Hamilton, New Zealand
[3]Hume Consulting Ltd, Hamilton, New Zealand

Abstract

There are many cases of surf break degradation and mismanagement worldwide. Discourse between surf break users and those who may compromise the resource is often the result of a void in baseline information and a lack of clear methods for assessing surf breaks and managing surfing resources. Following numerous incidences of poor management and inappropriate process, a 3-year project was undertaken to establish baseline monitoring systems and to develop management guidelines. The project was completed in September 2018. The introductory sections of the guidelines provide the legislative context and information regarding the relevant policies relating to surfing resources in New Zealand, and information concerning the significance of surf breaks at local, regional and national scales. The guidelines are written in three main sections, i) Guidelines for Authorities, ii) Guidelines for Resources Users and Consent Applications, and iii) Additional Information for Users. The Guidelines for Authorities section consists of a set of recommended steps, of increasing complexity and financial overhead, to effectively manage surfing resources within a given jurisdiction. The Guidelines for Resources Users and Consent Applications section considers the types of assessments and level of detail required to fairly assess the impacts of certain activities on surfing resources. The Additional Information for Users contains a set of appendices providing detail, discussion and methodology concerning stakeholder engagement; identification of surf breaks; swell corridors; risk assessments; monitoring; physical surf science; surfing resources; data collection methods; and example consent conditions. The benefits of the guidelines are to enable informed decision-making by council staff, engineers and consultants about activities in coastal areas that relate to or influence the functionality of New Zealand's surf breaks. The guidelines, which were released in a beta version in October 2018 to provide a feedback period, are a world-first and much of the content is applicable to surf breaks worldwide.

Keywords: Surfing, surf breaks, resource management, guidelines.

1. Introduction

The history of surfing in New Zealand predates the popularization of surfing in the 1950s and 1960s, with Māori partaking in wave riding using kōpapa (boards) and pōhā (bags of kelp) [5,6] before European contact. The Hawai'ian surfer Duke Kahanamoku travelled to New Zealand in 1915 and put on many demonstrations of the type of surfing going on across the Pacific Ocean. By the 1920s and 1930s, New Zealanders were riding solid wooden boards and in 1958 the concept of surfing smaller boards was introduced at Piha. By the 1960s, New Zealand had a surfboard building industry and a growing population of surfers.

In New Zealand, surfing has participation numbers equivalent to rugby [17], with the country's top athletes competing at the highest level on the world stage. Surfing in New Zealand is a serious draw card for tourism, with "world class" waves advertised in almost every coastal region. Emphasis on the importance of surf breaks as coastal resources was manifested in the inclusion of surf breaks in Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS) [8], which includes a list of 17 Surf Breaks of National Significance in Schedule 1. The impetus for the surfing community to provide submissions on the NZCPS was derived from cases of surf break mismanagement and degradation, not only in New Zealand but globally [9,11,15,16].

The NZCPS was developed under the Resource Management Act (1991). While the RMA and NZCPS provide a legislative framework for the sustainable management of surf breaks in New Zealand, there have been a number of cases that have led to appeals in environment court, facilitated mediation and high court Injunctions [11]. These appeals are based on maintaining the integrity of natural processes that influence surf break environments, and on a variety of aspects important to surf break users including accessibility and environmental health [13].

In many of these cases, disputes have revolved around: the collection of data, or lack thereof; the level of study required; and the methodologies implemented. In response to these common themes, a project, funded by New Zealand's Ministry for Business, Innovation and Employment in 2016, entitled *Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance* was initiated. As the project titled suggests, a major output of the project was to develop an adoptable consensus on how surfing resources are sustainably managed in

New Zealand, with this consensus taking the form of a set of guidelines.

An aim of the project was to ensure the guidelines assist: authorities with decision making; resource users to understand their responsibilities; and stakeholders to understand the resources and how they may be affected. The objectives were to provide: information on the legislative and social context of surf breaks; an understanding of the physical characteristics of surf breaks and how they function; a description of factors that can compromise their amenity value; specific methodologies for management of surfing resources for authorities and consent applicants; information to assist with the identification, study, monitoring and sustainable management of surf breaks.

This paper presents the process undertaken to develop *Management Guidelines for Surfing Resources* [3] (referred to henceforth as "the guidelines"), the structure of their use and focuses on some of the key tools and content.

2. Methods

Atkin *et al*. [2] provide details on the methodologies implemented as part of the wider research project. Here the methodologies are briefly summarised.

The collation of local knowledge at 7 study sites (Piha (South), Whangamata Bar, Manu Bay, Lyall Bay, Wainui Beach, Whareakeake and Aramoana; Figure 1) was achieved though stakeholder engagement at advertised meetings and qualitative surveys (analogue and online).

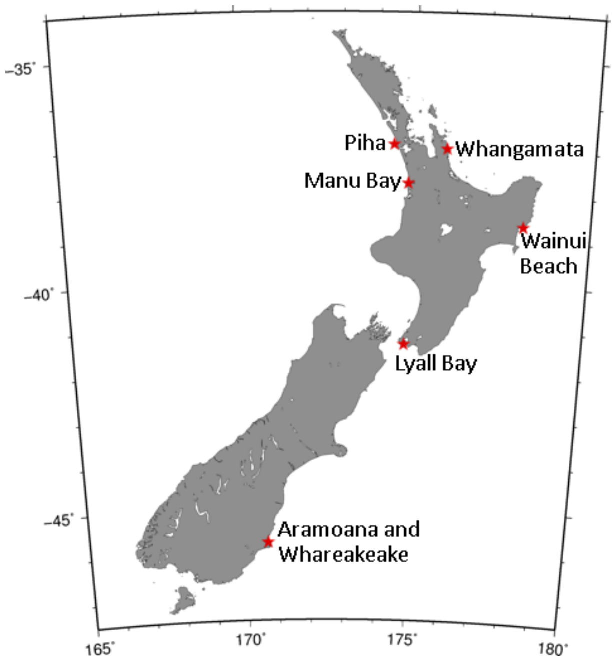


Figure 1. Map of New Zealand showing the location of the seven study sites.

The consultation process aimed to be inclusive with participation from local and non-local, surfer and non-surfer, business owners, Māori and Pākehā (non- Māori); with meaningful engagement and consultation with tangata whenua (local Māori, people of the land) who have kaitiakitanga (guardianship) of each area.

A substantial component of developing the guidelines was the review of existing literature, including everything from historical accounts to published articles and technical reports. Initial geomorphologic assessments of the 7 study sites were combined with the literature review to develop an initial characterisation of each site which included surf break functionality.

Data collection over the duration of the project included remote video imaging systems; hydrographic surveys; and, surfer behaviour while accessing and riding waves. A result of the literature review, stakeholder engagement, and data collection is disseminated in several peer reviewed articles contributing to the expanding body of literature regarding surf science [1,7,11] and surfing resource management [9,11,12,18], which the guidelines [3] reference directly.

3. Structure of the Guidelines

The primary section headings from the guidelines, excluding peripheral information, are presented in Table 1. The introduction of the guidelines contains concise information concerning the background of surfing resources and the legislative context of surfing resource management in New Zealand. Also included are sub-sections on: the difference between a surfing resource and the surf break; the significance of surf breaks [12], the rights of mana whenua (local iwi) [18]; and, the purpose of the guidelines.

Table 1. Abridged Table of Contents from Atkin *et al.* [3]

Section 1	Introduction
Section 2	Guidelines for Authorities
Section 3	Guidelines for Resource Users and Consent Applicants
Section 4	Additional Information for Users
Section 5	Summary and Outlook
Appx A.	Physical Surf Science
Appx B.	Surfing Resource
Appx C.	Engagement with Māori
Appx D.	Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance
Appx E.	Consent Conditions and Monitoring

The aim of providing such supplementary information (beyond that of implementable management strategies) is to provide users who are foreign to the concept of surfing resource management with the context of implementation within the New Zealand setting and the importance of surfing resources to the country's wellbeing.

Sections 2 and 3 provide clear steps to guide the assessment process for guideline users, while avoiding technical detail and specific methodologies. Instead, short lists of resources, tools and references are provided. These lists are first expanded upon in Section 4, and then underpinned by a set of detailed appendices.

The steps provided in Section 2 aim to provide specific direction for authorities responsible for the management of surfing resources. The section is broken down into 6 steps:

Step 1: Identify Surf Breaks
Step 2: Construct Swell Corridors
Step 3: Threats and Risk Assessment
Step 4: Surfing Resources in Policy and Plans
Step 5: Baseline Studies
Step 6: Monitoring to Assess Change

Steps 1 and 2 are included to support council officers identifying, mapping and characterising surf breaks in their region. These steps have relatively low overheads and require minimal resources, and result in basic management tools (Figure 2). They are essentially a detailed interpretation of what the NZCPS requires of subnational authorities.

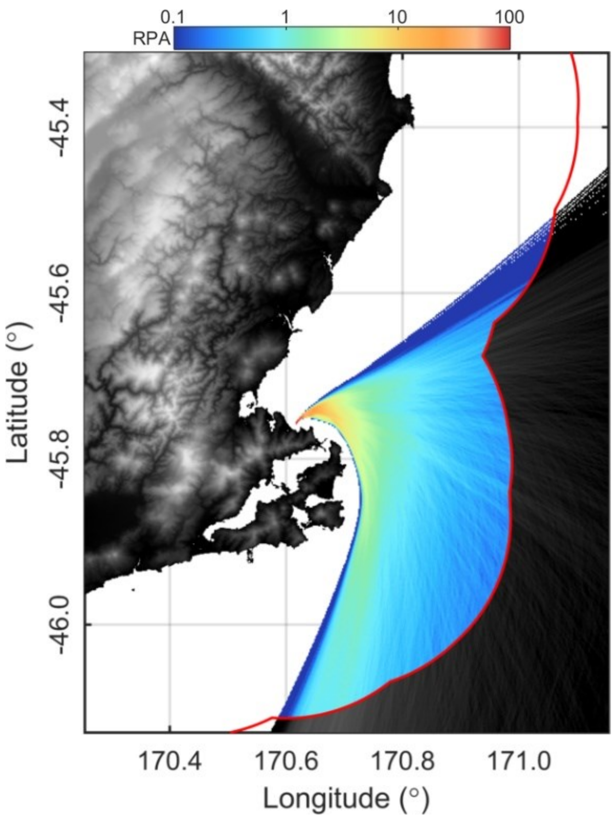


Figure 2. Relative Percentage Activity to construct the swell corridor for Whareakeake, with the Territorial Sea limit (red line) [1].

In Step 3, the threats and risk assessment are provided to aid in prioritising resources for further steps such as monitoring. Step 4 lists the relative items in the RMA (Sections 5, 6 and 7) and NZCPS (Policies 2, 6, 13, 15 and 16). Steps 5 and 6 are proactive and recommend the collection of baseline data, especially for those sites identified in Step 3 as being particularly at risk.

Section 3 is most relevant to consent applicants who need to assess the potential impact of an activity on a specific surf break(s) as part of a consent application. The process follows the content of Section 2, guidelines for authorities, however a much greater level of detail relating to the characteristics of the surf break and the threats an activity pose is required.

Section 4, "Additional Information for Users", provides expanded descriptions of steps prescribed in Sections 2 and 3 and covers: Stakeholder Engagement; Identification of Surf Breaks; Swell Corridors; Threats and Risk Assessment; Cultural Impact Assessment; Surfing Resources in Policy and Plans; Baseline Monitoring; Considerations for Consenting Authorities; and, Detailed Characterisation

4. Threats

A relatively substantial portion of the guidelines is focussed on Section 2.3, "Step 3: Threats and Risk Assessment". This section contains a table of some 34 different activities, threats and/or sources that were identified through literature reviews and public consultation. These activities, threats and/or sources fall under 4 subcategories: Hinterland, Catchment and Waterways; In and around a Surf Break Area (SBA); Nearshore, Offshore and Swell Corridor; and, Social and Technological. For each activity/threat/source, the potential effects on surfing resources are provided with examples and/or references from New Zealand and overseas where surf breaks have been affected and/or been assessed, and potential mitigation options. The activities, threats and/or sources are presented in Table 2.

5. Risk Assessment

Table 3 through Table 6 present the risk assessment tools from the guidelines [3]. Table 3 draws on a large body of technical literature to provide a tool that allows for an evaluation of a surf breaks vulnerability and sensitivity. It categorises surf breaks using the geomorphological categories described by Mead [10], and later Scarfe [14]; the context of which is described in Appendix A of the guidelines. The sensitivity is evaluated on the size of material that comprises the seabed, form fine sand to consolidated rock, and the reliance of surfing wave quality on any sediment transport regime.

Table 2. Potential activities/threats/sources of surf break integrity. Modified from Atkin *et al.* [3]

Hinterland, Catchment and Waterways	**In and around an SBA**	**Nearshore, Offshore and Swell Corridor**	**Social and technological**
Forestry	Beach nourishment	Aquaculture	Beach closure for events
Quarrying	Construction of jetties, groynes, breakwaters, boat ramps and other hard structures in the nearshore	Dredging of port/harbours approach channels	Different surfing abilities
Material extraction in waterways (e.g. dredging)	Dune planting programs	Dredge spoil disposal	Different surfing (water) craft
Port and marina construction, development and maintenance	Nearshore dredge operations	Large scale seabed mining	Improved equipment
Restriction of access by land owners	Reclamation	Oil Spills	Improved facilities, infrastructure and access
Runoff from rural and urban point and diffuse sources	Recreational fishing	Wind or wave energy arrays	Increasing surfer population
Transgressive dune field: Planting or; development.	River/Stream training		Management requirements
	Shoreline armouring		Overcrowding
			Surf forecasts and knowledge
			Surf tourism
			Use of SBA beyond surfing

Table 3. Surf Break Sensitivity Rating. Replicated from Atkin *et al.* [3]

	Potential Break Type	**General Material Size**	**Wave Quality Reliance on Sediment Transport Regime**
1	Rock Ledge; Reef	Consolidated Rock	Low
2	Reef; Point		
3	Point; Beach; Delta		
4	Beach; Delta		
5	Delta	Fine Sand	High

Table 4 presents the consequence of activity assessment information. This table provides a definition of the consequence rating and examples for each consequence category to aid users in this evaluation. Table 5 provides user with a tool to estimate the likelihood of an impact of an activity, with examples to assist in this assessment. The sensitivity assessment (Table 3) ties directly in to the likelihood assessment with thresholds/ranges of sensitivity values referenced in the additional definition information. Table 6 brings together the category values established from the Consequence of Activity and Impact of Activity tables. The result is a risk rating of either Low, Moderate, High or Extreme to fit in with standard risk assessment methodology.

Table 4. Consequence of activity. Replicated from Atkin *et al.* [3]

Consequence of activity	**Category**	**Definition**	**Example**
Catastrophic	1	Permanent/irreparable damage to/loss of the whole surf break(s)	Occupation of SBA Major reclamation Port construction
Major	2	Activity permanently effects access to and/or enjoyment of a surfing resource; and/or activity results in on-going health and safety issues; and/or potential for physical changes to a large part of the SBA; and/or a permanent change to the natural character, aesthetic or wilderness attributes of the surfing resource.	Complete loss of access Reduced ride length. Reduced wave quality Wastewater outfall Coastal protection works Coastal landscape altered by coastal development
Significant	3	Activity temporally effects, for sustained periods of time, access to and/or enjoyment of a surfing resource; and/or activity results in health and safety issues. No physical impacts	Turbid water Contamination Regulated access Ski-lane
Minor	4	Activity temporally effects access and/or enjoyment to a surfing resource for relatively short periods of time (e.g. <24 hours). No physical impacts	Beach closure for sporting events/surf carnival

Table 5. Likelihood of Impact. Replicated from Atkin *et al.* [3]

Likelihood of impact	**Category**	**Definition**
Very Likely (Permanent/ Frequent)	A	Will obviously occur frequently and/or permanently, activity being undertaken in SBA; examples exist of impact; and/or a sensitivity rating: 5
Likely (Frequent)	B	Potential for activity to occur frequently, activity being undertaken in or near to SBA; and/or similar examples exist; and/or sensitivity rating: 3-4
Moderate (Occasional)	C	Potential for activity to occur, activity being undertaken near to SBA or within catchment; and/or examples exist; and/or sensitivity rating: 2-3
Unlikely (Remote)	D	Activity unlikely to occur, activity being undertaken outside of catchment and/or embayment; no examples exist; and/or sensitivity rating: 1-2
Highly Unlikely (Rare)	E	Activity high unlikely to occur, activity being undertaken outside of catchment and/or swell corridor no examples exist; and/or sensitivity rating: 1

Table 6. Risk Rating. Replicated from Atkin *et al.* [3]

Risk Rating Table					
		Catastrophic-1	Major-2	Significant-3	Minor-4
Very Likely	A	Extreme	Extreme	Extreme	High
Likely	B	Extreme	Extreme	High	Moderate
Moderate	C	Extreme	Extreme	High	Low
Unlikely	D	Extreme	High	Moderate	Low
Highly Unlikely	E	High	High	Moderate	Low

6. Appendices

Appendix A brings together ~50 years of surf science literature, which is reliant on classic oceanographic concepts. Appendix B expands on Section 1.2.1 of the guidelines and provides details for differentiating between a surf break and a surfing resource and leverages the content of Orchard *et al*. [12]. Appendix C provides links to resources to aid with respectful and meaningful engagement with Māori. Appendix D provides background on the overall research project (see 1. Introduction). Appendix E replicates real examples of conditions for sustainable surf break management imposed on consent applicants in New Zealand.

7. Discussion

Methodologies and tools specific to surfing resource management have been collated/developed and established in one comprehensive document: *Management Guidelines for Surfing Resources*. One of the objectives of the project was to create an easily referenceable document, with the main content light and digestible.

Activities, threats and sources range in spatial scale (e.g. local, regional and global). Each of these can have different time frames. The effects of an activity/threat/source can be temporary, or permanent; similarly, although some effects can be mitigated, many cannot. They can have negative or positive effects on wave quality and the surf break environment. Some threats are more common at specific geomorphic types of surf breaks (e.g. channel dredging, issues with boat traffic, and water quality are more common to river/estuary bar breaks) [3].

The list of threats to surfing resources developed from public consultation and the literature review is extensive, but by no means exhaustive. More recent discussion by surfing and surf science researchers established an extensive list of activities, threats and sources to surfing resources that eclipsed the 34 instances documented in this work [4].

Through public consultation, literature reviews of technical documentation, legal proceedings and published articles, methodologies have been developed for both management authorities and and those wishing to undertake activities in and around surfing resources. The guidelines also provide a reference point for stakeholders to understand how activities in the coastal zone, regarding surfing resources, may affect them.

A qualitative risk assessment methodology has been developed using well-known coastal geomorphologic settings and concepts for sensitivity ratings, and consequence categories that draw on examples of known surf break degradation. As far as the authors are aware, this is the first published methodology of its kind.

The value of a risk assessment is that it allows authorities to develop a “watch list”. This should aid in decision making processes by showing which surf breaks require priority when allocating resources such as those required for monitoring. The guidelines state that “*any surf break, surfing resource or SBA receiving a risk rating of extreme requires immediate action and resources should be directed to enabling Baseline Studies if not already undertaken; and, Baseline Monitoring should be initiated immediately should the consequence be major or catastrophic”* [3].

While the qualitative risk assessment methodology provides a relatively simple method, it does require an in depth knowledge of coastal processes, surf science and surf break dynamics (detailed characterisation). Furthermore, it suffers from the short comings of many qualitative assessment by being subjective. The method also lacks any information to allow for economic considerations.

The recommendation is that an initial review/update of the *Management Guidelines for Surfing Resources* will be undertaken after 2 years from publishing. To keep the guidelines applicable, by referencing the latest relevant research from both New Zealand and overseas, annual reviews and 5 yearly updates will be undertaken.

8. Conclusion

This paper describes the rationale, methodology and content of a project to develop guidelines for the sustainable management of surfing resources in New Zealand, with global applicability. The resulting *Management Guidelines for Surfing Resources* were released in October 2018 in beta format to allow a period of feedback from users.

The guidelines are aimed at assisting:

- authorities tasked with implementing policies and plans,
- resource users and applicants, to manage expectations and responsibilities with respect to resource consent requirements where proposed activities may affect surfing resources.
- Stakeholders, to understand how developments might affect the amenity value of surf breaks and the responsibilities of those proposing the developments.

It is expected that the Management Guidelines for Surfing Resources in New Zealand will make the RMA (1991) resource consenting processes easier to follow and reduce escalation to environment court appeals, meditation and other legal and social conflicts.

Following on from New Zealand's ground breaking establishment of the Resource Management Act, New Zealand Coastal Policy Statement and the inclusion of surf break specific policy in the form of Policy 16, New Zealand once again leads the world in environmental resource management by developing the first national guidelines for surf resource management. The volume of technical information applicable to the management of surfing resources, including the principles of surf science through to links relating to the engagement of indigenous people of Aotearoa, mean it is a valuable document for developers, prospectors, public servants and authorities, practitioners and stakeholders worldwide.

9. Acknowledgements

The authors would like to thank the Ministry of Business, Innovation and Employment (UOWX502) for funding this project; all the participants involved with stakeholder consultation; members of the steering committee from containing representation from the Department of Conservation, Landcare Research, Surfbreak Protection Society, Surf Life Saving New Zealand, Waikato Regional Council, Auckland Council, and Lincoln University; and those experts who reviewed the guidelines: Professor Andrew Short, Graeme Silver, Dr Greg Borne, Associate Professor Hamish Rennie, James Carley, Matt McNeil, Michael Gunson, Rick Liefting, Dr Shaun Awatere and Shane Orchard. We are grateful for all your contributions.

10. References

[1] Atkin, E. A and Greer D. (2018), A Comparison of Methods for Defining a Surf Break's Swell Corridor. Manuscript submitted to Journal of Coastal Research.

[2] Atkin, E. A, Mead, S. T., Bryan, K., Hume, T. and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. Proceedings of the 23th Australasian Coasts and Ports Conference, Cairns, Australia, 21-23 June 2017.

[3] Atkin, E. A, Bryan, K., Hume, T., Mead, S. T., and Waiti, J., (2018), Management Guidelines for Surfing Resources. Raglan, New Zealand: Technical Group on Surfing Resources.

[4] Association for Surfing Research (2019), Second Annual Meeting, Impact Zones & Liminal Spaces Conference, 28th April 2019, San Diego State University.

[5] Beattie, H. (1919), Traditions and legends collected from the natives of Murihiku (Southland, New Zealand). The Journal of the Polynesian Society, 28(XI), 212–25.

[6] Best, E. (1924), Games and pastimes of the Maori. Wellington, New Zealand: A. R. Shearer.

[7] Bryan, K.B, Davies-Campbell, J, Hume, T. and Gallop, S.L., (2019), The influence of sand bar morphology on surfing amenity at New Zealand beach breaks, Manuscript submitted to Journal of Coastal Research.

[8] Government of New Zealand, (2010). New Zealand Coastal Policy Statement. Wellington; Department of Conservation.

[9] Hume, T, Mulcahy, N and Mead, S., (2019), An overview of changing usage and management issues in New Zealand's surf zone environment. Paper submitted.

[10] Mead, S. T., (2000). Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs. PhD thesis, University of Waikato, New Zealand. Pp 209 + appendices.

[11] Mead, S. and Atkin, E, (2019), Managing Issues at New Zealand's Surf Breaks, Paper submitted

[12] Orchard, S., Atkin, E.A. and Mead, S.T. (2018), Development of the Regional Significance Concept for Surf Break Management in New Zealand. Manuscript submitted to Journal of Coastal Research.

[13] Peryman, P. B., and Orchard, S. (2013), Understanding the Values and Management Needs of New Zealand Surf Breaks, Lincoln Planning Review, 4(2).

[14] Scarfe, B., (2008). Oceanographic Considerations for the Management and Protection of Surfing Breaks. PhD thesis, University of Waikato, New Zealand.

[15] Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T., (2009a). Sustainable management of surfing breaks: an overview. Reef Journal, 1(1), 44–73.

[16] Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T., (2009b). Sustainable Management of Surfing Breaks: Case Studies and Recommendations. Journal of Coastal Research, 25(3), 684–703.

[17] Sport New Zealand (2015). Sport and Active Recreation in the Lives of New Zealand Adults. 2013/14 Active New Zealand Survey Results

[18] Waiti, J, and Awatere, S, (2019) Kaihekengaru: Māori surfers' and a sense of place. Manuscript submitted to Journal of Coastal Research.

5 Applicability of Management Guidelines for Surfing Resources in California

Publication details:

Atkin, E.A., Reineman, D.R., Reiblich, J. and Revell, D.L., 2020. Applicability of Management Guidelines for Surfing Resources in California. Shore & Beach, 88(3), pp.53-64.

The publisher has been granted permission to reproduce this article in the published form. Pagination of the reproduced article is carried over from publication and not synchronised with the main body of this thesis.

The development and publication of the Guidelines broke new ground in surfing resource management and this attracted attention outside of ANZ. This exposure presented the opportunity to collaborate with researchers from the United States to leverage the learnings of not just the Guidelines but the process of their development. The publication presented in this chapter compares the governance setting for surfing resource management in ANZ and coastal California and explores the utility of the Guidelines outside of ANZ. The work highlights possible mechanisms and steps for more effective management in the state of California, with identification of surfing resources being a priority. The paper emphasizes the potential benefits of developing globally applicable, generic guidance for surfing resources.

Figure 1 presents the swell corridor, based on the Relative Percentage Activity (RPA), determined from the long-term wave climate, for Aramoana. The background to RPA and the development of swell corridors is provided in Chapter 6.

Applicability of management guidelines for surfing resources in California

By

Edward A. Atkin,[1] Dan R. Reineman,[2] Jesse Reiblich,[3] and David L. Revell[4]

1) eCoast Marine Consulting and Research, 18 Calvert Road, Raglan, Aotearoa New Zealand. University of Waikato, Knighton Road, Hamilton 3240, Aotearoa New Zealand; e.atkin@ecoast.co.nz, +64 2108 200 821

2) Environmental Science and Resource Management Program, California State University Channel Islands, 1 University Drive, Camarillo, California 93012, USA

3) Virginia Coastal Policy Center, William & Mary Law School, Williamsburg, Virginia, 23187 USA

4) 200 Washington Street, Suite 201, Santa Cruz, California 95060 USA

ABSTRACT

Surf breaks are finite, valuable, and vulnerable natural resources, that not only influence community and cultural identities, but are a source of revenue and provide a range of health benefits. Despite these values, surf breaks largely lack recognition as coastal resources and therefore the associated management measures required to maintain them. Some countries, especially those endowed with high-quality surf breaks and where the sport of surfing is accepted as mainstream, have recognized the value of surfing resources and have specific policies for their conservation. In Aotearoa New Zealand surf breaks are included within national environmental policy. Aotearoa New Zealand has recently produced Management Guidelines for Surfing Resources (MGSR), which were developed in conjunction with universities, regional authorities, not-for-profit entities, and government agencies. The MGSR provide recommendations for both consenting authorities and those wishing to undertake activities in the coastal marine area, as well as tools and techniques to aid in the management of surfing resources. While the MGSR are firmly aligned with Aotearoa New Zealand's cultural and legal frameworks, much of their content is applicable to surf breaks worldwide. In the United States, there are several national-level and state-level statutes that are generally relevant to various aspects of surfing resources, but there is no law or policy that directly addresses them. This paper describes the MGSR, considers California's existing governance frameworks, and examines the potential benefits of adapting and expanding the MGSR in this state.

KEYWORDS: Coastal, environmental, governance, policy, legislation, surf breaks.

Manuscript submitted 24 March 2020, revised & accepted 17 July 2020.

Surf breaks are discrete coastal locations where waves break in a manner that is conducive to the sport of surfing (Walker *et al.* 1972; Walker 1974; Mead 2000); they are finite, valuable, and vulnerable natural resources (Lazarow *et al.* 2008; Scarfe *et al.* 2009a; 2009b; Reineman *et al.* 2017; Mead and Atkin 2019) that can span very large areas (Mead 2000; Mead and Black 2001a,b; Mead *et al.* 2003; Atkin and Greer 2019), and are often little understood due to a lack of site specific data (Atkin *et al.* 2017).

Managing surf breaks requires careful consideration of a variety of factors that operate across a range of spatial and temporal scales, and transcend beyond just the breaking of waves, including: unique coastal geomorphology; coastal, estuarine and riverine processes; coastal access; water quality; ecosystem processes; social/cultural dynamics; and almost always, episodic metocean phenomena (Corne 2009; Reineman *et al.* 2017; Reineman and Ardoin 2018; Atkin *et al.* 2019; Reiblich and Reineman 2019). As coastal resources, surf breaks are susceptible to a variety of alterations, both natural and anthropogenic, that can impact surfing wave quality and/or surfing resource use and enjoyment.

The attention surf breaks receive in resource management varies at local, national and international scales (Farmer and Short 2007; Short and Farmer 2012; Reiblich 2013; Reiblich and Reineman 2019; Scheske *et al.* 2019; Orchard *et al.* 2019; Orchard 2020). Some countries such as Peru, Australia, and Aotearoa New Zealand (hereafter Aotearoa), those especially endowed with high-quality surf and where the sport of surfing is mainstream, have provided management and legal frameworks for the conservation of surfing resources.

Aotearoa was the first country to include surf breaks within a legal framework. Orchard (2020) provides a detailed description of the management strategy developed in Aotearoa. In summary, under the Resource Management Act 1991 (RMA), a ground-breaking piece of legislation that prioritized environmental objectives through the promotion of sustainability, all regulatory authorities are subject to the New Zealand Coastal Policy Statement 2010 (NZCPS; Department of Conservation 2010). Several sections of the NZCPS are directly or indirectly relevant to surfing resources. Policy 16 of the NZCPS identifies 17 *Surf Breaks of National Significance* (SBNS) that are protected by *ensuring that activities in the coastal environment do not adversely affect the surf breaks; and avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks*. Policy 13, *Preservation of natural character,* and Policy 15, *Natural features and natural landscapes,* in combination with Policy 16, have led to a surfing resource management setting in Aotearoa that transcends management of just the SBNS (Perryman, 2011; Perryman and Orchard 2013; Skellern *et al.* 2013; Atkin *et al.* 2017; Mead and Atkin 2019; Orchard *et al.* 2019).

Despite the NZCPS, there are numerous cases of surf breaks being affected by activities in the coastal environment (Skellern *et al.* 2013; Atkin *et al.*, 2017; Atkin, 2019; Atkin *et al.*, 2019a; Mead and Atkin 2019). In many of these cases, a lack of data and clear methodologies led to drawn out disputes with resource managers struggling to implement the purpose of the RMA and effectively uphold the intent of the NZCPS (Atkin, *et al.* 2017). In 2018, *Management Guidelines for Surfing Resources* (MGSR; Atkin *et al.* 2018; 2019a) were published in Aotearoa to help clarify the regulations and with the goal of reducing disputes between community groups, development interests, and coastal industries. The NZCPS provides a description of a *surf break*, based on geomorphic and physical parameters. However, managing surf breaks requires careful consideration of a variety of factors, including physical characteristics that can be spatially removed from the location of the surf break itself (Atkin and Greer 2019; Atkin *et al.* 2019b; Mead and Atkin 2019; Orchard *et al.* 2019). Atkin *et al.* (2018; 2019a) use the term *surfing resources* in Aotearoa, noting that components such as the rarity and uniqueness, naturalness, level of use, economic value, and historical and cultural associations all contribute to the surfing experience (Orchard *et al.* 2019), in addition to physical processes and attributes (the surf break itself). The use of "resource" is in alignment with terminology used in legislative and regulatory frameworks managing other asset classes, including, for example, fisheries and minerals.

In the United States, surfing first spread from its Polynesian origins in the State of Hawaií to Santa Cruz in California in the late 1880s, and then beyond in the early 20th century (Warshaw 2010). Surfing now occurs in every coastal state in the U.S., including the Great Lakes states. In these, and in some land-locked states, hydraulic jumps or standing waves in rivers are also surfed. While it was considered a fringe activity and counterculture in the 1960s, surfing has now

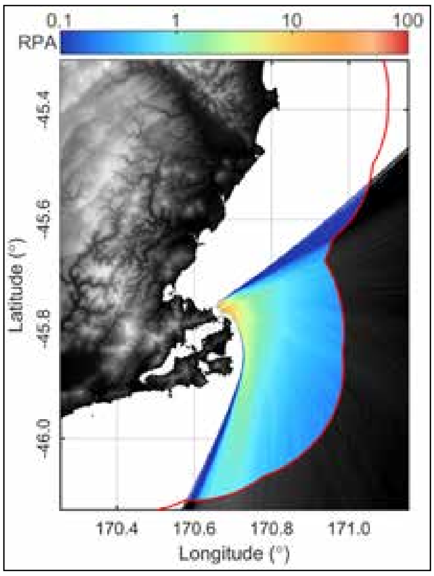


Figure 1. Relative Percentage Activity (RPA) to show swell corridor footprint for Aramoana, Otago, South Island, Aotearoa including the territorial sea limit (red line).

entered the national consciousness, with an international professional competition circuit, a multibillion-dollar surf industry, intensive travel and recreation opportunities, and it has shaped the cultural identities of coastal communities. Despite the consistent growth and popularity of surfing, management of surfing resources in the U.S. is virtually non-existent; the result is surfing resources, or accessibility to them, becoming threatened, degraded, or destroyed (e.g. Killer Dana and Trestles in Southern California and Ruggles in Rhode Island; Nelsen *et al.* 2013).

While the United States lacks the legal foundation and specific policy framework adopted by Aotearoa, a variety of laws at the national and state level are relevant to surfing resource management. This paper describes the MGSR, considers California's existing governance frameworks, and examines the potential benefits of adapting and expanding the MGSR in this state.

Table 1.
Abridged table of contents of Atkin *et al.* (2019a).

Section 1.	Introduction
Section 2.	Guidelines for Authorities
Section 3.	Guidelines for Resource Users and Consent Applicants
Section 4.	Additional Information for Users
Section 5.	Summary and Outlook
Appendix A.	Physical Surf Science
Appendix B.	Surfing Resources
Appendix C.	Engagement with Māori
Appendix D.	Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance
Appendix E.	Consent Conditions and Monitoring

MANAGEMENT GUIDELINES FOR SURFING RESOURCES

The *Management Guidelines for Surfing Resources* (MGSR; Atkin *et al.* 2019a) were developed over the course of a three-year research project (Atkin *et al.* 2017) that leveraged local knowledge collated through stakeholder engagement, detailed reviews of existing literature, and the collection of social and physical data. Table 1 provides the primary section headings of the MGSR. The MGSR were written to be accessible to a broad audience, including stakeholders and decision makers, but are underpinned by detailed technical information and supporting appendices.

There is crossover between the practical steps in *Section 2: Guidelines for Authorities* and *Section 3: Guidelines for Resource Users and Consent Applicants*. Here these steps are presented jointly.

1. Identify surf breaks

The identification of surf breaks reduces disputes and increases awareness around surf break management and accessibility (Department of Conservation 2017a, b). The process for effective identification of surf breaks should include:

- A thorough literature review, likely to include written surf guides and web based resources;
- Meaningful stakeholder engagement with interviews, workshop sessions, and/or surveys, that should aim to:
- Understand surf break parts/sections and basic dynamics, including common and colloquial names,
- Delineate the Surf Break Area (SBA) (Atkin and Greer 2019),
- Understand access routes and points to the SBA,
- Discuss observed changes in the coastal environment considered relevant to the surfing resource;
- Compilation of the information in a database, along with additional information such as photographic evidence, that can be freely and readily accessible to authorities and the public;
- Understanding the significance of surfing resources in a management context (Orchard *et al.* 2019).

2. Swell corridors

The NZCPS defines a swell corridor as "*the region offshore of a surf break where* *ocean swell travels and transforms to a 'surfable wave.'"* Spatially defining a SBA's swell corridor and producing a georeferenced feature (Atkin and Greer 2019) creates a planning tool that allows users to assess whether activities could block or modify waves travelling through the swell corridor of a surf break; ultimately this aids the resource management decision making process. Proposed activities falling within the bounds of a swell corridor should trigger further investigation or detailed assessments. Figure 1 provides an example from Atkin and Greer (2019) who used Relative Percentage Activity to describe the swell corridor at seven surf breaks in Aotearoa. This method highlights the offshore areas of importance to the functionality of the surf break.

3. Threats and risk assessment

The threat and risk assessment process reveals the potential for impacts to surfing resources. A risk assessment requires an understanding of all the elements that contribute to the use and enjoyment of a surfing resource. The *Surf Break Sensitivity* rating (Table 2) draws on technical literature to provide a tool that allows for an evaluation of a surf break's sensitivity. It categorizes surf breaks using geomorphological categories (Mead 2000; Scarfe 2008; Atkin *et al.* 2019a) and considers both the size and mobility of the material that comprises the seabed and the reliance of surfing wave quality on any sediment transport regime. The sensitivity assessment ties into the *Likelihood of Impact* assessment (Table 3). The *Consequence of Activity* (Table 4) ratings are framed around NZCPS terminology. The Likelihood and Consequence ratings are used to establish a risk rating (Table 5).

Examples of applying the risk assessment methodology for the cases of Mangamaunu and Takapuna in Aotearoa are presented in Table 6. At Mangamaunu, a SBNS, a rock revetment with reclamation was proposed for construction along the foreshore adjacent to the point break. The consenting process for this proposal was fast tracked under emergency legislation (Rennie 2018; Rennie *et al.* 2018). Applying the threat and risk assessment methodology indicated that the risk rating for this activity would be extreme. In contrast, at Takapuna the risk rating for a fiber optic cable installation, requiring trenching through the intertidal zone and offshore, was found to be low.

Table 2.
Surf break sensitivity rating tool replicated from Atkin *et al.* (2019a).

	Surf break type	General material size	Wave quality reliance on sediment transport regime
1	Rock ledge; reef	Consolidated rock	Low
2	Reef; point		
3	Point; beach; delta		
4	Beach; delta		
5	Delta	Fine sand	High

Table 3.
Likelihood of impact rating tool replicated from Atkin *et al.* (2019a).

Likelihood of impact	Category	Definition
Very likely (permanent/frequent)	A	Will obviously occur frequently and/or permanently, activity being undertaken in SBA; examples exist of impact; and/or a sensitivity rating: 5
Likely (frequent)	B	Potential for activity to occur frequently, activity being undertaken in or near to SBA; and/or similar examples exist; and/or sensitivity rating: 3-4
Moderate (occasional)	C	Potential for activity to occur, activity being undertaken near to SBA or within catchment; and/or examples exist; and/or sensitivity rating: 2-3
Unlikely (remote)	D	Activity unlikely to occur, activity being undertaken outside of catchment and/or embayment; no examples exist; and/or sensitivity rating: 1-2
Highly unlikely (rare)	E	Activity unlikely to occur, activity being undertaken outside of catchment and/or swell corridor no examples exist; and/or sensitivity rating: 1

4. Surfing resources in policy and plans

In Aotearoa, resource management is implemented by subnational authorities (regional, district, and city councils) through the drafting of policy instruments and plans (e.g. Regional Coastal Plan). Incremental reviews of policy instruments and plans by authorities provide the opportunity to incorporate surfing resource relevant terminology.

5. Baseline studies and monitoring

Sustainable management of resources, especially those as dynamic as surf breaks, relies on an understanding of the resource itself. A thorough understanding of the resource underpins adaptive resource management and the development of the MGSR (Atkin *et al.* 2017). Establishing a long-term environmental baseline is critical to understanding natural variation and both differentiating it from and detecting, managing and mitigating, anthropogenic change. Furthermore, a thorough understanding hedges against the risk of shifting baseline syndrome for these resources (Reineman *et al.* 2017).

Datasets that benefit baseline studies and ongoing monitoring (Atkin *et al.* 2019a) include, but are not limited to: collation of local and existing knowledge (via stakeholder engagement and literature reviews); remote video imaging systems; hydrographic surveys (bathymetry); and, Geographical Positioning System (GPS) data of surfers whilst riding and accessing waves (Borrero *et al.* 2019). Specific aims of baseline studies and ongoing monitoring are to establish wave breaking characteristics such as peel angle (Walker *et al.* 1972; Hutt *et al.* 2001; McIntosh *et al.* 2018), breaking intensity (Mead and Black 2001c), ride lengths (Mead and Borrero 2017), access points (Reiblich and Reineman 2019), functional components (Mead and Black 2001a, b), mechanics

Table 4.
Consequence of activity rating tool replicated from Atkin *et al.* (2019a).

Consequence of activity	Category	Definition	Example
Catastrophic	1	Permanent/irreparable damage to/loss of the whole surf break(s)	Occupation of SBA Major reclamation Port construction
Major	2	Activity permanently affects access to and/or enjoyment of a surfing resource; and/or activity results in on-going health and safety issues; and/or potential for physical changes to a large part of the SBA; and/or a permanent change to the natural character, aesthetic or wilderness attributes of the surfing resource.	Complete loss of access Reduced ride length Reduced wave quality Wastewater outfall Coastal protection works Coastal landscape altered by coastal development Turbid water
Significant	3	Activity temporarily affects, for sustained periods of time, access to and/or enjoyment of a surfing resource; and/or activity results in health and safety issues. No physical impacts	Contamination Regulated access Ski-lane
Minor	4	Activity temporarily affects access and/or enjoyment to a surfing resource for relatively short periods of time (e.g. <24 hours). No physical impacts	Beach closure for events

Table 5.
Risk rating tool modified from Atkin et al. (2019a) with consequence ratings on the top row and likelihood ratings in the first column.

	1	2	3	4
A	Extreme	Extreme	Extreme	High
B	Extreme	Extreme	High	Moderate
C	Extreme	Extreme	High	Low
D	Extreme	High	Moderate	Low
E	High	High	Moderate	Low

(Mead and Black 1999; Mead and Black 2001a,b,c; Atkin *et al.* 2019b; Mead and Atkin 2019) and any maintenance mechanisms (e.g. Liria *et al.* 2009; Atkin *et al.* 2013; Mead and Atkin 2019).

In summary, the MGSR provides a science-based, adaptive, stakeholder-engaged process for surfing resource management. Identifying surf breaks and their respective swell corridors provides the basis for conducting comprehensive threat and risk assessments of the impact a proposed activity poses to surfing resources and equips decision-makers with tools to aid the consenting process. Developing policy and planning documents that target surfing resource protection at multiple levels of government can provide adequate consideration and protection of the resource. Lastly, collecting baseline data on surfing resources establishes the critical checkpoint against which any future changes, natural or human-caused, can be compared, guards against the risk of shifting baselines, and increases general and specific understanding of the resource.

U.S. FEDERAL SETTING

The U.S. lacks a comprehensive framework for ocean management and preservation (Crowder *et al.* 2006). Instead, a host of federal laws (greater than 100) and dozens of federal agencies all share complex and overlapping jurisdictions for different activities and resources in marine and coastal environments (U.S. Commission on Ocean Policy 2004). While several national-level statutes are generally relevant to various aspects of surfing resources, there is no national-level interpretation for how surfing resources should be managed.

No federal U.S. law standardizes the boundary between public trust tidelands, where recreational activities like surfing are often protected by law, and private property areas above the waterline, where the public trust does not apply. In California and Florida, the private/public property boundary is Mean High Water (MHW) and therefore access to the nearshore is legally permissible. MHW is the 19-year average of high tide elevations. Oregon law is more expansive, featuring beaches that are accessible to the public up to the vegetation line (Oregon Beach Bill 1967). Maine allows property ownership down to the Mean Low Water Mark, and while Maine courts have relied on the public trust doctrine to protect fishing, hunting, and SCUBA diving, surfing resources are not offered protection (Reiblich and Reineman 2019).

The National Environmental Policy Act (NEPA) requires evaluation of the environmental effects of any federal governmental activity or action through environmental assessments and environmental impact statements. The review process considers impacts to biological, ecological, historical, cultural, archaeological, and other protected resources, as well as to water and air quality. Critically, the review allows for public comment and participation. NEPA provides the opportunity to challenge federal coastal activities that may impact surfing resources, such as breakwater and harbor construction (Oram and Valverde 1994).

Table 6.
Application of the risk assessment methodology for the cases of Mangamaunu and Takapuna.

Site	Mangamaunu	Takapuna
Activity	Rock revetment and reclamation directly adjacent to surf break, in the SBA. Permanent change.	Trenching of telecommunications cable through intertidal zone and offshore. Temporary activity
Break type	Point Break	Beach and reef breaks
Seabed composition	Boulder/Sand	Sand and rock
Descriptive summary	Exposed, very high-quality points. Surf Break of National Significance. Multiple sections offering high performance maneuvers. Easily accessible. Wilderness value.	Sheltered beach and reef breaks. Inconsistent, poor to average wave quality, however highly valued and utilized urban surf break. Suitable for learners to competent surfers. Good facilities and access.
Surf break sensitivity	3	3
Consequence of activity	Major — 2	Minor — 4
Likelihood of impact	Very likely — A	Moderate — C
Risk rating	Extreme	Low

Section 303 of the Clean Water Act (CWA) regulates pollution of the waters of the U.S., including a discharge permit system, water quality standards, and the regulation of pollution loads on water bodies used for recreational activities. These CWA provisions aim to reduce pollution in waterways which offers downstream benefits to surfing resource users. CWA Section 404 limits dredging and filling of water bodies, including during projects such as breakwater construction which can threaten the integrity of a surf break (Reiblich 2013; Oram and Valverde 1994).

The National Historic Preservation Act (NHPA) is a federal law protecting structures and areas of historical and cultural significance. The NHPA provides a process for adding sites to a National Register of Historic Places, supervised by the National Park Service, and policies to "*contribute to the[ir] preservation.*" The NHPA was invoked in the case of Malibu's Surfrider Beach, which was added to the National Register of Historic Places under the NHPA (Blum 2015) in 2018.

The Coastal Zone Management Act (CZMA) enacted in 1972 seeks to protect public access to, and the environmental quality of, the nation's coastlines, including for recreational opportunities, though these protections are balanced against economic development. The CZMA provides states the right to review federal actions that can potentially impact a state's coastline. Federal actions are evaluated by the state for consistency with the state's own coastal protection laws. However, this "*federal consistency review*" is only allowed prior to federal action (in states with approved coastal zone management plans) and cannot be initiated after the harmful action is underway. The CZMA incentivizes states to determine for themselves those resources and management priorities that are significant to their coasts through the development of state coastal plans.

CALIFORNIA STATE SETTING

In 2018, California declared surfing the "*official state sport*" with the passage of Assembly Bill 1782 (AB 1782). AB 1782 recognizes the historic, cultural, and economic significance of surfing in California and the role California has played in surfing globally. The bill identifies six "*world-famous surf breaks*" in California — Malibu, Trestles, Mavericks, Rincon, Steamer Lane, and Huntington — and notes surf events at Hermosa Beach, Manhattan Beach, Redondo Beach, Torrance, Huntington Beach and Mavericks. The bill does not, however, address the vulnerability of these or any other surf breaks, nor provide any policies or processes for their preservation or management.

California laws generally implement, and in most cases strengthen, their federal "parent" versions (Dana 2008) and this includes *inter alia* the California Environmental Quality Act (CEQA; state version of NEPA) and Porter-Cologne Water Quality Control Act (Porter-Cologne; state version of CWA).

The California Coastal Act (CCA) is the state's implementing legislation for the CZMA. The CCA, enacted in 1976, defines and guides management of the state's Coastal Zone, with public access to the shoreline as its fundamental goal. The CCA protects "*Coastal areas suited for water-oriented recreational activities that cannot readily be provided at inland water areas.*" The CCA does not protect surf breaks specifically for surfing, however, the CCA's precursors sought to do so. In 1972, the interim California Coastal Commission (CCC) completed the California Coastal Plan which identified surfing resources worthy of protection, including: Trestles, Steamer Lane, San Onofre, Cardiff Reef, Hollister Ranch, and Black's Beach (California Coastal Zone Conservation Commissions 1975), and called for acquiring specific parcels for surfing and other recreational uses (e.g. Hammonds Meadow). This interim coastal plan was never adopted, and the final CCA does not include these provisions. The CCC has exercised its permitting authority (via Coastal Development Permits [CDPs]) for several surfing related purposes, including to protect surf break-relevant watersheds (e.g. blocking the Hwy 241 Toll Road extension to San Onofre State Beach upstream of the Trestles complex of surf breaks), to protect surfing-relevant access (e.g. opening the restrictive access measures at the Dana Point Strands), and to address gender equality in surfing (requiring the Mavericks surf contest organizers to admit female surfers as a condition of obtaining their event permit).

California's Coastal Zone jurisdiction extends from 3 nm offshore to ~1,000 yards inland from MHW (though with many deviations). Chapter 3, Article 2 of the CCA protects access to public trust tidelines and therefore access to many surfing locations. This part of the CCA also provides for other relevant amenities such as parking or showers but does not explicitly state the protection or management of surfing resources themselves. The Coastal Zone is managed by several state agencies including the CCC (open, Pacific coast), the Bay Conservation and Development Commission (San Francisco Bay), the California State Lands Commission (CSLC; offshore below mean high water), and the State Coastal Conservancy (SCC; non regulatory).

The location of MHW determines the jurisdiction of these state agencies, California's local city and county governments and the boundaries between public trust and (potentially) private property). The CCC has the primary coastal management regulatory authority for land above MHW within the Coastal Zone (of the open coast) and evaluates projects based on consistency with the CCA. Below MHW, the CSLC also regulates subtidal and intertidal lands and manages these areas for public trust uses. In some areas, CSLC grants public trust authority to other entities, such as city or port authorities for navigation, commerce and fishing purposes. Under permit by CSLC, grantees can develop infrastructure suitable to those uses (e.g. jetties or wharves).

Below MHW, the CCC retains coastal development permit authority. Above MHW, and outside of the CCC area of original jurisdiction, local governments (cities and counties) can set coastal management policy and obtain permit-granting authority, provided that they prepare a Local Coastal Program (LCP) under the CCA and have it certified by the CCC. Furthermore, the CCC provides guidance and support to local governments as they prepare and update their LCPs; in 2018, for example, the CCC released updated Sea Level Rise (SLR) Policy Guidance, which acknowledges the vulnerability of surf breaks by calling for "*policies to promote research on sea level rise impacts to recreational activities like surfing*" (CCC 2018).

The Marine Managed Areas Improvement Act (MMAIA) of 2000 defines six marine protected area categories: state marine reserve; state marine park; state marine conservation area; cultural preservation area; recreational management area; and water quality protection area. Each category addresses specific resources that are generally focused on marine biota. Currently, there are not any marine protected areas that specify surf breaks. However, the terminology used in describing how State Marine Conservation Areas, State Marine Parks, State Marine Cultural Preservation Areas and State Marine Recreational Management Area may be established is extremely relevant to surfing resources. For example, State Marine Conservation Areas may be established for the preservation of "*outstanding or unique geological features.*" High-quality surf breaks are atypical on most coastlines, and the geomorphology of these surf breaks are likely comprised of unique geological features. State Marine Parks may be established to preserve areas with geological and recreational value. One of the goals of establishing State Marine Cultural Preservation Areas and State Marine Recreational Management Areas is to protect "*sites of historical, archaeological, or scientific interest*" and "*provide, limit, or restrict recreational opportunities… while preserving basic resource values for present and future generations,*" respectively. Many of California's surf breaks meet several, if not all, of these criteria.

LOCAL-LEVEL COASTAL MANAGEMENT IN CALIFORNIA

At the sub-state level, local jurisdictions have limited authority over management of coastal resources. Under the Coastal Act, local governments are charged with preparing and implementing LCPs. Once the CCC has certified an LCP, local governments assume responsibility for permitting. The jurisdiction of LCPs is limited to MHW and above. LCPs are required to be periodically updated to remain effective (CCC 2013) and amendments to LCPs are evaluated under the Coastal Act. The state guidance on updates encourages local governments to more thoroughly consider the threats posed by sea level rise along with preferred adaptation strategies along shorelines.

The CCC's 2013 LCP Update Guide provides the information under 11 sections. All sections of the guide are relevant to surfing resources and/or describe activities that can impact surfing resources. LCPs are stated as essential to reaching the goal of maximum public access to coastal and public recreation areas. The LCP Update Guide recommends areas to be addressed in an LCP, the following points within the guide relate to surfing resources:

- Full mitigation of the impacts of development on public recreation (Section 1).
- Inventories of recreational areas and zoning for adequate recreation (Section 2).
- Watershed management policies that identify potential pollutant sources and changes in watershed hydrology that may adversely impact coastal resources (Section 3).
- Mapping, inventories and monitoring of Environmentally Sensitive Habitats and Other Natural Resources (Section 4).
- Measures to preserve the special values and character of the community (Section 7).

The last point comes from Section 7. Scenic & Visual Resources. Surf breaks have aesthetic values that are recognized by those both in and outside the surfing community (Atkin *et al.* 2019a).

Surf breaks in Malibu, CA and Santa Cruz, CA were designated as World Surfing Reserves (WSRs) in 2010 and 2012, respectively. The WSR designation is awarded by Save The Waves Coalition, an international environmental not-for-profit organization. The designation offers no formal legislative protection; it is however a community driven program that acknowledges the international significance of surfing resources. Local Stewardship Councils (formed through the WSR designation process) have been shown to catalyze dialogue, and eventually action, in formal governmental settings. For example, in Santa Cruz, a working group facilitated by Save the Waves in cooperation with the city and other stakeholders was formed to address chronic poor water quality issues at Cowells Beach. In 2020, after substantial efforts to track and address sources of pollution, Cowells was removed from a statewide list of beaches with poor water quality. The CCC passed a resolution supporting the designation of WSRs in California (CCC 2010). As of March 2020, dialogue with the City of Santa Cruz has included consideration for: the mapping of specific surf breaks; identification of optimal and marginal conditions through local knowledge interviews; the application of local knowledge to interpreting the impact of coastal

Table 7.

Linkages between practical MGSR components and legislation and/or policies in California. The first MGSR component, 1. Identify Surf Breaks, is broken into four subcomponents

Component	Policy	Relevance in California
1. Identify surf breaks — general	Assembly Bill 1782	Specifically references 11 surfing locations in CA.
	CCA>CCC>LCP	Specify appropriate location, type, and scale of new or changed uses of land and water.
	NRHP	Identifies cultural/historical areas and provides for their consideration if an impact is pending; used to designate Surfrider Beach, Malibu, CA.
	WSR	Designations are made by an NGO and lack formal govt. protections.
1. Identify surf breaks — access	Public Trust Doctrine	Protects access to water, tidelands, and resources below MHW; codified generally in Coastal Act.
	Coastal Act	Enshrines protection of public coastal access for recreational, other purposes
	CWA/ Porter-Cologne	Works to maintain and improve coastal water quality and thus ensure safe accessibility of the ocean; focus on beneficial uses, which can include immersive, recreational activities, like surfing.
1. Identify surf breaks — delineation	National parks, monuments, marine sanctuaries	Area-based protections provided by these federal laws can target areas of historic, cultural, or recreational significance, including coral reefs, seamounts, and beaches; currently not explicitly applied to protect any surfing resources.
	CCA>CCC>LCP	Specify appropriate location, type, and scale of new or changed uses of land and water and can identify surfing areas; LCP policies regarding resources below MHW are not binding on CCC decision-making jurisdiction there.
	MMAIA	Several Marine Managed Areas types could be used to create protected areas of recreational and cultural significance but have not yet been designated to protect surfing resources.
	WSR	Program/designation process includes mapping of surfing areas.
1. Identify surf breaks — surf break dynamics	NEPA/CEQA	Require review of potential impacts of proposed activities or actions and consideration of many factors, including cultural and recreational impacts; also provide pathways for public engagement.
	CWA	Section 404 stipulates a regulatory and permitting process for the dredge and fill of materials in the nation's waters, including in the coastal ocean; process could provide a check on activities with the potential to interrupt coastal process, including sediment import, transport, and export from the nearshore.
	CCA>CCC>LCPs	Provides clear guidance on permitting for proposed activities in the coastal zone and nearshore that likewise could impact coastal processes, including, e.g. coastal armoring.
2. Swell corridors	CZMA	Provides California with review of federal activities beyond 3 nm for consistency with Coastal Act.
	CCA>CCC	Defines Coastal Zone in California, gives CCC authority to permit activities in Zone that are consistent with Act's provisions to protect access and resources.
	CCA>CSLC	Subject to additional CCC review, the CSLC grants permits to modify and leases to utilize public trust seafloor below MHW, also subject to CCA policies. The Coastal Zone hosts a range of seabed features that contribute to the functionality of surf breaks on the California coast.
3. Threats and risk assessment	NEPA/CEQA	Risk assessments form part of any comprehensive environmental assessments; public participation allows stakeholders interested in surf break protection to air concerns through formal process; this is ad hoc, does not ensure surf protection, and is contingent on engaged stakeholders.
4. Surfing resources in policy and plans	CCA>CCC>LCP	Updates to Local Coastal Programs provide the opportunity for surfing resources to be identified and protections and evaluation methods incorporated into LCP permitting with the caveat that LCPs lack jurisdiction below MHW.
5. Baseline studies and monitoring	CCC Sea Level Rise Policy Guidance	Recommends LCP "policies to promote research on sea level rise impacts to recreational activities like surfing;" this language is non-binding.
	NEPA/ CEQA	Environmental review under both laws requires some amount of documentation of baseline conditions and, depending on proposed project and mitigation, monitoring during/after completion. For certain resources, e.g. an endangered bird or stream turbidity, study/monitoring protocols are well established; less so for surfing resources.

activities, hazards and/or climate change adaptation strategies on each surf break; and a recreational cost benefit analysis to inform decision-makers as to the consequences of future adaptation pathways.

DISCUSSION

The following considers the five MGSR components previously described in the context of a California resource management framework. Table 7 provides a summary of the practical components from the MGSR and the legislation and/or policies in California to which they relate and under which they could be implemented.

Surfing resources in policy and plans

There are multiple policy instruments relevant to the management of surfing resources in California. Determining which entities have jurisdiction over an activity is critical to effectively applying law and policy. Local governments (e.g. cities and counties) with certified LCPs have jurisdiction on the coast down to MHW; the CCC and/or CSLC have jurisdiction of the coastal zone to 3 nm offshore; the federal government has jurisdiction from 3 nm to 200 nm offshore. This straightforward delineation of jurisdiction is nuanced through consistency review provided by CZMA and CCA specifications for the CCC's areas of original jurisdiction, as well as the certification status of a local government's LCP. Because they can encompass large areas and are susceptible to modifications from the upper reaches of a watershed to the continental shelf, surfing resources implicate multiple jurisdictions and multiple levels of government.

There is no direct mention of surfing in any resource management legislation at either the California state or U.S. federal level. However, some of California's local governments have prepared LCPs that specifically recognize important surfing resources. For example, the City of Santa Cruz's LCP characterizes Steamer Lane as a "*prime surfing point*" (City of Santa Cruz 1992). This characterization should be strengthened to better reflect not only Steamer Lane's significance, but the historical, cultural and recreational significance of all surf breaks in the City of Santa Cruz, many of which are enumerated in the WSR designation of certain surfing areas within the city. More local jurisdictions could take the approach of identifying surfing resources in their coastal management policies and legislation.

Summarily, there is no mention of surfing at the national statutory level in Aotearoa; the Resource Management Act only refers to amenity, aesthetic, recreational, scientific, historical, spiritual, and cultural values. However, the New Zealand Coastal Policy Statement, a compulsory national policy, explicitly identifies surfing through Policy 16: Surf Breaks of National Significance, which identifies 17 surf breaks listed in Schedule 1 of the NZCPS. The degree of management conferred on all surf breaks in Aotearoa has been effected through the clear mandate in the NZCPS recognizing all coastal resources but also through the interpretation of other relevant Policies considering, *inter alia*, natural character, natural features, natural landscapes, natural elements, processes and patterns, public open space, and walking access. These coastal resource terms are broadly consistent with the terminology in the federal CZMA and the CCA, and with the CCC's mandates and recent Sea Level Rise Policy Guidance.

While the NZCPS provides guidance for subnational authorities, it is the policy instruments created at the regional, district and city level that are most relevant to the applied management of surfing resources. The legal framework in the U.S. allows for surfing resource-specific terminology to be incorporated into policy at state and lower levels. Doing so would be a step toward proactive surfing resource management, where a localized version of the *Guidelines for Authorities* (Atkin *et al.* 2019a) could be applied either through amendments to state legislation or through local ordinances in the form of LCPs. The most comparable equivalent to Aotearoa's Regional Coastal Plans in California are LCPs. However, the jurisdiction of LCPs generally ends at MHW, compared to an NZ Regional Coastal Plan which extends 12 nm offshore. Despite this, LCPs still have a vital role in sustainable surfing resource management as they address key issues surrounding coastal access, water quality, sediment and watershed management, and the enjoyment and aesthetic value of recreational resources that can be defined and prioritized at local scales.

In Aotearoa, surfing resources were first considered in national policy during a review of the NZCPS, and it has been during the redrafting of short- to long-term Coastal Plans that surfing resource management has been considered at a local to regional level. Intermittent revisions of policy, policy instruments and plans provide an opportunity to incorporate surfing resources into the existing coastal resource management framework. In Aotearoa, by 2020, nine out of 16 regions have identified Surf Breaks of Regional Significance (Atkin *et al.* 2015; Atkin and Mead 2017; Orchard *et al.* 2019; Orchard 2020), with one region, the Waikato, also considering their potential Surf Breaks of Local Significance (SBLS) and/or "secret spots," by designating Known Surfing Coastlines (Atkin 2017; Atkin and Mead 2017; Orchard *et al.* 2019).

One of the key differences between Aotearoa and California is the division of jurisdictions over coastal, nearshore, and ocean environments. The Coastal Zone in California extends 3 nm offshore, and ~1,000 yards inland from MHW, with substantial width deviations to encompass significant resource areas (e.g. estuaries) and for other reasons. In comparison, the NZCPS covers the Coastal Environment, which generally extends from the summit of the first dominant ridge to the limit of the territorial sea (12 nm offshore). The importance of this is that it includes catchment or watershed management (with critical implications for sediment management, i.e. the "sandshed"; Revell *et al.* 2007), which has significance for surfing resources as the surf break itself may be a function of watershed and estuarine processes (e.g. a delta-type surf break, Liria *et al.* 2009; Atkin *et al.* 2013). Furthermore, surfing resource users are exposed to potential water quality issues for much longer periods of time than the average water user and in critical locations, such as the entrance to tidal inlets. For multiple aspects of surfing resources, the mismatches in scale and jurisdiction within the U.S. system can thus provide management challenges.

Identification of surf breaks

The identification of surf breaks in an official list or catalogue is a low-cost, proactive exercise that could be executed at local (city or county) or state levels. The CCC's coastal access program is a database of coastal access points in the state, including their locations and amenities (CCC 2019). Surf breaks are occasionally included as amenities at coastal access points listed in the database. This practice is not systematic, many databases are informal, and where mentioned, any specific detail about the surfing resource is limited.

Lacking an overarching policy framework for the explicit consideration and management of surfing resources, designating surf breaks and SBAs through existing policy mechanisms is a reasonable approach. For example, management policies of National Parks and Monuments are underpinned by comprehensive management plans designed to protect resources while also providing for their enjoyment. Development and promulgation of management plans (as federal actions) are themselves subject to environmental review under NEPA and a similar situation exists at the state level in California through CEQA.

In California, the MMAIA creates several categories of marine managed areas for the explicit purposes of protecting cultural and recreational resources. Surfing resources in California have not yet been targeted for designation under MMAIA, though it seems like an applicable policy vehicle, particularly as surf breaks meet many of the criteria enumerated as worthy of protection under the Act, including their location on, relatively, geologically-unique sections of coastline that are often associated with terms such as rarity, wilderness and naturalness, and hold historical and cultural associations that contribute to the surfing experience (Orchard *et al.* 2019). Furthermore, they can be found in areas of significant biodiversity, and may be a product of particular terrestrial landscapes (e.g. a transverse dune field) or riverine and estuarine processes (e.g. an ebb tidal delta), or other natural processes. Including a surf break as a natural resource component in an application for a marine managed area designation under MMAIA, would likely strengthen the case for designation in a number of area categories.

Listing surf breaks on the Register of Historic Places under the NHPA does not provide the highest level of legal protection, but does add recognition to the importance of the resource during any environmental review process (e.g. Malibu, CA; Blum 2015). NGO-led designation, like the World Surfing Reserve program, can also add recognition to the importance of a surfing resource (e.g. Santa Cruz; CCC 2010), though in the latter case of these non-governmental designations, such consideration would be entirely optional. Likewise, the WSR designation of Surfrider Beach in Malibu may have contributed to its successful bid for listing on the Register of Historic Places.

Surf breaks are valued as a coastal resource in most surfing nations for their health, social and economic benefits to people and communities, despite a general lack of legislative and policy frameworks to sustainably manage them. Yet the value of a surfing resource to different sectors can quickly diminish if they are not accessible. Chapter 3, Article 2 of the CCA provides for other coastal amenities such as parking, showers, beach volleyball courts and coastal trails, but does not explicitly identify surf or surfing. The public trust doctrine mirrors the CCA's goal of providing maximum public access to and along the coast, LCPs should reflect this goal. When authorities or experts are charged with identifying, mapping or making inventories under LCPs (e.g. delineating surf break areas) the identification of access points and access methods (e.g. boat, ATV, foot, bike etc.) should also be included. The documentation of surf break access points and methods could contribute to the Coastal Act's fundamental goal of providing maximum public access.

Swell corridors

The NZCPS considers a swell corridor as a critical part of the surf break and which should be considered during any permitting process. Understanding the relevant boundaries of this area informs the decision-making process as activities within a swell corridor can affect the integrity of a surfing resource. In Aotearoa swell corridors have been established out to the 12-nm territorial sea boundary, in line with regional authority jurisdiction; by contrast, state authorities in the U.S. have jurisdiction to 3 nm. This difference has several ramifications. Firstly, a 3-nm offshore extension of a surf break area still falls under the resource-protective policies of the CCA and authority of the CCC and/or CSLC. Secondly, surfers tend to utilize longer period waves which can interact with the seafloor far from the shore (e.g. a wave with a 12 s period will interact with the sea floor in ~112 m depth; at 18 s, this is ~250 m). Effective preconditioning of waves has been shown to operate at continental shelf scales down to surf break-specific focusing (Mead and Black 2001a, b; Mead *et al.* 2003; Atkin and Greer 2019; Atkin *et al.* 2019b), so it is likely, given that the continental shelf of California ranges from ~0.2 nm to ~13 nm, with an average of ~3 nm (Emery 1952), that surf break-relevant processes in the swell corridor will exceed the 3 nm jurisdiction in some cases. State-level enumeration of and protections for surfing areas could support state-level consistency determinations of potential actions in federal waters from 3-200 nm.

Threats and risk assessment

A significant avenue for considering surfing resources through environmental management in the U.S. is through the environmental review process codified in NEPA and, in California, CEQA. However, environmental review is still conducted on a case-by-case basis with no systematic inclusion or evaluation of surfing resources. In such cases, the *Guidelines for Resource Users and Consent Applicants* can be referenced by those seeking to undertake activities in the coastal environment — as well as by stakeholders and the surfing resource user community seeking to ensure that surf breaks implicated during environmental review processes are appropriately considered. The MGSR Guidelines could be adapted to the policy framework of the U.S. to support consideration of surf breaks and the formalization of a protocol for evaluating and monitoring in the environmental review processes. There is a clear mandate for environmental review from NEPA and CEQA, and a Threats and Risk Assessment of surfing resources per the MGSR, fits well within that process. The Threats and Risk Assessment methodology in the MGSR is based on a coherent understanding of a surf break's geomorphological setting, maintenance mechanisms, and surf break dynamics. This type of understanding would come from identification steps and baseline studies, which would constitute a key component of environmental review. This is however, assuming that a surf break is recognized as a valued resource within a management context. Recognition as a valued resource often relies on public participation and comment, both of which are provided for but not guaranteed by the NEPA/CEQA environmental review process.

The terminology used in the *Consequence of Activity* designation in the MGSR's Threats and Risk Assessment may well require adaptation to be consistent with U.S. policies and/or documentation.

Baseline studies and monitoring

Part of the impetus for developing the MGSR and the underlying research project through which they were developed, was to address the requirements for baseline data (Atkin *et al.* 2017; Atkin *et al.* 2019a; Mead and Atkin 2019). The CCC's LCP Guidance (CCC 2013) and SLR Guidance (CCC 2018), as well as both NEPA and CEQA, reference monitoring and/or baseline conditions in relation to natural resources. Those surfing locations recognized in AB 1782, designated as World Surfing Reserves (Santa Cruz and Malibu), and/or listed on the Register of Historic Places (Malibu) could prove a good starting point. Monitoring is a key element in the environmental review process required under NEPA and CEQA and has the potential to be initiated on a case-by-case basis, should the surfing resource be implicated during a permit application process. Transitioning to a directed, systematic, data-driven approach is critical in establishing proactive surfing resource management. The monitoring of surfing resources, in theory, requires no government approval and can be implemented by any individual or group. In Aotearoa, the bulk of surfing resource monitoring is undertaken by the Aotearoa New Zealand Association for Surfing Research, a charitable trust charged with maintaining the monitoring stations, datasets, and the MGSR.

Other considerations

The MGSR certainly have applicability outside of coastal California, including in other coastal states where surfing is significant. Application in other states will necessarily involve adaptation to those states' specific coastal governance settings. The MGSR could be redrafted in more generic terms to provide more direct relevance to a wider user group. A benchmark to strive for within a coastal context for such generic guidelines is the U.S. Army Corps of Engineers' Coastal Engineering Manual, which is used globally. The MGSR are underpinned by Aotearoa's legislation and unique culture, leading to the use of specific terminology, which will likely limit uptake.

CONCLUSION

Surfing resource management in California is currently bereft. Shifting to a proactive approach where surfing resources are explicitly identified and managed under policies at all levels of government, including Local Coastal Programs under the California Coastal Act and the state marine managed area system under the Marine Managed Areas Improvement Act, would be a first step toward implementing management guidelines like those in Aotearoa. Until this proactive shift occurs, the *Guidelines for Resource Users and Consent Applicants* can serve as a reference guide of Best Management Practices (BMPs). Such BMPs are most relevant during the environmental review process and of value to both proponents and opponents for all proposed activities in the coastal zone.

To date, protection of surfing resources has resulted primarily from the engagement of surfing stakeholders represented by not-for-profit conservation groups. Recent actions in California — including the establishment of two World Surfing Reserves, listing of Malibu on the Federal Register of Historic Places, designation of surfing as the official state sport, and the high-profile defeat of coastal development proposals that threatened surf breaks — together suggest a broad shift in the collective attitude towards recognizing the importance of surfing resources in California. This shift is driven by a variety of factors, including increased participation in surfing state- and world-wide and an associated increase in our understanding of the economic, social, cultural, mental, physiological, and other benefits that surfing provides, combined with a growing recognition that surf breaks are vulnerable, finite natural resources.

The MGSR were developed within Aotearoa's unique cultural setting and legislative framework. However, the MGSR's consideration of multiple socio-economic factors and physical processes at a range of scales are key to effectively and sustainably managing surfing resources and can be applicable to surfing resources in many other global settings. They are, therefore, beneficial to jurisdictions outside of Aotearoa whose governance structures lack surfing-specific guidance.

Despite the parochial and complex development history of the MGSR in Aotearoa, there is clear relevance to surfing resource management within a California setting as demonstrated here, despite the jurisdictional mismatches implicating multiple federal, state, and local policies. Incorporating surf specific terminology into Aotearoa policy took place during a national-level review of the nation's Coastal Policy Statement, followed by the development and subsequent review of subnational policy instruments. A similar effort aimed at the clear and explicit articulation of surfing values, vocabulary, and surfing resources within the U.S. and/or California policy frameworks would likely be necessary to facilitate comprehensive planning approaches to surfing resource management and the development of targeted, local guidelines.

ACKNOWLEDGEMENTS

This work has been undertaken as one of the first pieces produced from the newly established International Association for Surfing Research. The original research project that produced the Management Guidelines for Surfing Resources was funded by Aotearoa New Zealand's Ministry for Business, Innovation and Employment. The Aotearoa New Zealand Association for Surfing Research continues to maintain the guidelines.

REFERENCES

Atkin, E.A., 2017. *Known Surfing Coastlines in the Waikato Region*. eCoast Letter Report for Waikato Regional Council.

Atkin, E.A., 2019. "The New Zealand Association for Surfing Research and Management Guidelines for Surfing Resources." *New Zealand Coastal Society Conference*. Invercargill, New Zealand, November 2019.

Atkin, E.A., Greer, S.D., and V. Pickett, 2013. "Whangamata ebb tidal delta morphology and wave breaking patterns." *Coasts and Ports 2013: 21st Australasian Coastal and Ocean Engineering Conference and the 14th Australasian Port and Harbour Conference. Barton, A.C.T.: Engineers Australia, 2013*, 18-22.

Atkin, E. A., Gunson, M., and S.T. Mead. 2015. *Regionally Significant Surf breaks in the Greater Wellington Region*. eCoast technical report for Greater Wellington Regional Council.

Atkin, E.A., Bryan, K., Hume, T., Mead, S.T., and J. Waiti, 2018. *Management Guidelines for Surfing Resources – Beta Version*. Raglan, New Zealand: Technical Group on Surfing Resources.

Atkin, E.A., Bryan, K., Hume, T., Mead, S.T., and J. Waiti, 2019a. *Management Guidelines for Surfing Resources*. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research.

Atkin, E.A., Mead, S.T., Bryan, K., Hume, T., and J. Waiti, 2017. "Remote sensing, classification and management guidelines for surf breaks of national and regional significance." *Proc. 23rd Australasian Coasts and Ports Conference,* Cairns, Australia, 21-23 June 2017.

Atkin, E.A., and D. Greer, 2019. "A comparison of methods for defining a surf break's swell corridor." In: Bryan, K.R., and E.A. Atkin (eds.), *Surf Break Management in Aotearoa New Zealand. J. Coastal Research*, Special Issue No. 87, 70-77. Coconut Creek (Florida), ISSN 0749-0208.

Atkin, E.A., and S.T. Mead, 2017. *Surf Breaks of Regional Significance in the Waikato Region*. Waikato Regional Council Technical Report 2017/19. 64p.

Atkin, E.A., Mead, S.T., and D. Phillips, 2019b. "Investigations of offshore wave preconditioning." In: Bryan, K.R., and E.A. Atkin (eds.), *Surf Break Management in Aotearoa New Zealand. J. Coastal Research*, Special Issue No. 87, 78-90. Coconut Creek (Florida), ISSN 0749-0208.

Blum, M.L., 2015. *Protecting Surf Breaks and Surfing Areas in California*. Duke University Nicholas School of the Environment.

Borrero, J.C., O'Day, C., and J. Rifai, 2019. "Application of Rip Curl SearchGPS watch data for analyzing surf breaks." In: Bryan, K.R., and E. Atkin (eds.), *Surf Break Management in Aotearoa New Zealand. J. Coastal Research*, Special Issue No. 87, 55-69. Coconut Creek (Florida), ISSN 0749-0208.

CCC, 2010. "Resolution to support designation of world surfing reserves." California Coastal Commission. TH32a. [Online] https://documents.coastal.ca.gov/reports/2010/1/Th32a-1-2010.pdf

CCC, 2013. *Local Coastal Program Update Guide*. Revised Edition July 2013. California Coastal Commission.

CCC, 2018. *Updated Sea Level Rise Policy Guidance*. November 2018. California Coastal Commission.

CCC, 2019. *Yourcoast*. California Coastal Commission. Available online at: https://coastal.ca.gov/YourCoast/#/map; accessed 10 March 2020.

California Coastal Zone Conservation Commissions, 1975. "California Coastal Plan." California Agencies. Paper 91. https://digitalcommons.law.ggu.edu/cgi/viewcontent.cgi?article=1090&context=caldocs_agencies

City of Santa Cruz, 1992. "Local coastal program and coastal land use policies and maps." City of Santa Cruz General Plan/Local Coastal Program, 1990-2005. https://www.cityofsantacruz.com/home/showdocument?id=51167

Corne, N.P., 2009. "The implications of coastal protection and development on surfing." *J. Coastal Research*, 252, 427-434. doi: 10.2112/07-0932.1

Crowder, L.B., Osherenko, G., Young, O.R., Airamé, S., Norse, E.A., Baron, N., and J. Wilson, 2006. "Resolving mismatches in U.S. ocean governance." *Science*, 313(August), 617-618.

Dana, D., 2008. "Democratizing the Law of Federal Preemption." *Northwestern University Law Review*, 102(2), 507-550.

Department of Conservation, 2010. *New Zealand Coastal Policy Statement 2010*. Wellington: Department of Conservation.

Department of Conservation, 2017a. *Review of the effect of the NZCPS 2010 on RMA decision-making. Part 1 — Overview and key findings*. Prepared for the Minister of Conservation by the Department of Conservation. https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/coastal-management/review-of-effect-of-nzcps-2010-on-rma-part-one.pdf.

Department of Conservation, 2017b. *Review of the effect of the NZCPS 2010 on RMA decision-making. Part 2 — Background information*. Prepared for the Minister of Conservation by the Department of Conservation. https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/coastal-management/review-of-effect-of-nzcps-2010-on-rma-part-two.pdf.

Emery, K.O., 1952. "Continental shelf sediment of Southern California." *Bulletin of the Geological Society of America*, 63, 1105-1108.

Farmer, B., and A.D. Short, 2007. "Australian national surfing reserves – rationale and process for recognizing iconic surfing locations." *J. Coastal Research,* Special Issue 50, 99-103.

Hutt, J.A.; Black, K.P., and S.T. Mead, 2001. "Classification of surf breaks in relation to surfing skill." In: Black, K.P. (ed.), *Natural and Artificial Reefs for Surfing and Coastal Protection, J. Coastal Research*, Special Issue No. 29, 66-81.

Lazarow, N., Miller, M.L., and B. Blackwell, 2008. "The value of recreational surfing to society." *Tourism in Marine Environments*, 5(2), 145-158. doi: 10.3727/154427308787716749

Liria, P., Garel, E., and A. Uriarte, 2009. "The effects of dredging operations on the hydrodynamics of an ebb tidal delta: Oka estuary, northern Spain." *Continental Shelf Research*, 29, 1983-1994.

McIntosh, R., Atkin, E.A., and J. Davies-Campbell, 2018. "Development of an automated peel angle detection system for the Manu Bay surf break, Raglan, New Zealand." *New Zealand Coastal Society (IPENZ) Conference*. Gisborne, New Zealand, November 2018.

Mead, S.T., and J.C. Borrero, 2017. "Surf science and multi-purpose reefs." In: Green, D.R., and J.L. Payne (eds.), *Marine and Coastal Resource Management: Principles and Practice*. London, United Kingdom: Routledge, 328p.

Mead, S.T., 2000. *Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs*. Ph.D. thesis, University of Waikato, New Zealand. 209p + appendices.

Mead, S.T., Black, K.P., Frazerhurst, J., and B. Scarfe, 2003. "The effects of wave focusing on surfing reef site selection, surfing wave quality and ASR design at scales of inner continental shelf to sub-tidal reef." *Third International Artificial Surfing Reef Symposium,* Raglan, New Zealand 23-25 June 2003. ISBN 0-473-09801-6 2003.

Mead, S.T., and E.A. Atkin, 2019. "Managing issues at Aotearoa New Zealand's surf breaks." In: Bryan, K.R., and E.A. Atkin (eds.), *Surf Break Management in Aotearoa New Zealand. J. Coastal Research*, Special Issue No. 87, 13-22. Coconut Creek (Florida), ISSN 0749-0208.

Mead, S.T., and K.P. Black, 1999. "Configuration of large-scale reef components at a world-class surfing break: Bingin Reef, Bali, Indonesia." *Proc. Coasts and Ports '99, combined 14th Australasian Coastal and Ocean Engineering and the 7th Australasian Port and Harbor Conference*

Mead, S.T., and K.P. Black, 2001a. "Field studies leading to the bathymetric classification of world-class surfing breaks." In: Black, K.P. (ed.) *Natural and Artificial Reefs for Surfing and Coastal Protection. J. Coastal Research*, Special Issue No. 29, 5-21.

Mead, S.T., and K.P. Black, 2001b. "Functional component configurations controlling surfing wave quality at world-class surfing breaks." In: Black, K.P. (ed.) *Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research*, Special Issue No. 29, 22-32.

Mead, S.T., and K.P. Black, 2001c. "Predicting the breaking intensity of surfing waves." In: Black, K.P. (ed.) *Natural and Artificial Reefs for Surfing and Coastal Protection. J. Coastal Research*, Special Issue No. 29, 51-65.

Morris, P.H., (2013). "Monumental seascape modification under the Antiquities Act." *Environmental Law*, 43(1), 173-209.

Nelsen, C., Cummins, A., and H. Tagholm, 2013. "Paradise lost: threatened waves and the need for global surf protection." *J. Coastal Research*, 65(sp1), 904-908.

Oram, W., and C. Valverde, 1994. "Legal protection of surf breaks: putting the brakes on destruction of surf." *Stanford Environmental Law Journal*, 13(2), 401-448.

Orchard, S., 2020. "Legal protection of New Zealand's surf breaks: top-down and bottom-up aspects of a natural resource challenge." *Australasian J. Environmental Management*, 27(1), 6-21, DOI: 10.1080/14486563.2020.1719439.

Orchard, S, Atkin, E.A., and S.T. Mead, 2019. "Development of the regional significance concept for surf break management in Aotearoa New Zealand." In: Bryan, K.R., and E.A. Atkin (eds.), *Surf Break Management in Aotearoa New Zealand. J. Coastal Research*, Special Issue No. 87, 23-34. Coconut Creek (Florida), ISSN 0749-0208.

Perryman, B., 2011. *Surf Break Identification and Protection in the Gisborne District*. Gisborne District Council Report.

Perryman, P.B., and S. Orchard, 2013. "Understanding the values and management needs of New Zealand surf breaks." *Lincoln Planning Review*, 4(2).

Reiblich, J., 2013. "Greening the tube: paddling toward comprehensive surf break protection." *Environmental Law and Policy Journal*, 37(1), 45–71.

Reiblich, J., and D.R. Reineman, 2019. "Rhino chasers and rifles: surfing under the public trust doctrine." *J. Land Use and Environmental Law*, 34, 35-91.

Reineman, D.R., and N.M. Ardoin, 2018. "Sustainable tourism and the management of nearshore coastal places: place attachment and disruption to surf-spots." *J. Sustainable Tourism*, 26(2), 325–340. doi: 10.1080/09669582.2017.1352590

Reineman, D.R., Thomas, L.N., and M.R. Caldwell, 2017. "Using local knowledge to project sea level rise impacts on wave resources in California." *Ocean and Coastal Management*, 138. doi: 10.1016/j.ocecoaman.2017.01.020

Rennie, H., 2018. "Slow down: Coastal cycle trail 'less important' than protected surf break." Stuff – National. https://www.stuff.co.nz/national/105684699/slow-down-coastal-cycle-trail-less-important-than-protected-surf-break

Rennie, H., Simmons, D., Fountain, J., Langer, L., Grant, A., Craddock-Henry, N., and T. Wilson, 2018. "Post-quake planning — tourism and surfing in Kaikōura." In: Hendtlass, C., Borrero, J., Neale, D., and T. Shand (eds.), 2018. *Shaky shores — coastal impacts and responses to the 2016 Kaikōura earthquakes*. New Zealand Coastal Society, 44p.

Revell, D.L., Marra, J.J., and G.B. Griggs, 2007. "Sandshed management." *J. Coastal Research,* Special Issue 50: The International Coastal Symposium 2007, 93-98.

Scarfe, B., 2008. *Oceanographic Considerations for the Management and Protection of Surfing Breaks*. Ph.D. thesis, University of Waikato, New Zealand.

Scarfe, B.E., Healy, T., and H.G. Rennie, 2009a. "Research-based surfing literature for coastal management and the science of surfing — A Review." *J. Coastal Research*, 25(3), 537-559.

Scarfe, B.E., Healy, T., and H.G. Rennie, 2009b. "Sustainable management of surfing breaks." *J. Coastal Research*, 25(3), 684-703.

Scheske, C., Ruiz, M., Buttazzoni, J.E., Cvetich, N.S., Gelcich, S., Monteferri, B., and L.F. Rodríguez, 2019. "Surfing and marine conservation: Exploring surf-break protection as IUCN protected area categories and other effective area-based conservation measures." *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29, 195-211. doi: 10.1002/aqc.3054

Short, A.D., and B. Farmer. 2012. "Surfing reserves — recognition for the world's surfing breaks." *The Reef Journal*, 2, 1-14.

Skellern, M., Peryman, P., Orchard, S. and H. Rennie, 2013. *Planning Approaches for the Sustainable Management of Surf Breaks in New Zealand*. Report prepared for University of Auckland, Auckland Council, Bay of Plenty Regional Council and Surf Break Protection Society. 87pp.

U.S. Commission on Ocean Policy, 2004. *An Ocean Blueprint for the 21st Century: Final Report of the U.S. Commission on Ocean Policy*. http://govinfo.library.unt.edu/oceancommission/documents/full_color_rpt/welcome.html#full

Walker, J.R., 1974a. *Recreational surf parameters*. Hawaii, U.S.: LOOK Laboratory TR-30, University of Hawaii, Department of Ocean Engineering.

Walker, J.R., Palmer, R.Q. and J.K. Kukea, 1972. "Recreational surfing on Hawaiian reefs." *Proc. 13th Coastal Engineering Conference*.

Warshaw, M., 2010. *The History of Surfing*. San Francisco, CA: Chronicle Books.

6 A Comparison of Methods for Defining a Surf Break's Swell Corridor

Publication details:

Atkin, E.A. and Greer, D., 2019. A Comparison of Methods for Defining a Surf Break's Swell Corridor. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.

The publisher has been granted permission to reproduce this article in the published format. Pagination of the reproduced article is carried over from publication and not synchronised with the main body of this thesis. Page references to any errata are relevant to the publication.

The importance of a surf break's swell corridor is exemplified by the inclusion of a qualitative description in the glossary of the New Zealand Coastal Policy Statement 2010. This paper is the first published works on defining a swell corridor and introduces the Surf Break Area (SBA) concept, with the swell corridor as an offshore extension. The construction of swell corridors provides a planning tool for consenting authorities, proponents, and opponents. This work is a key reference within the Management Guidelines for Surfing Resources (Chapter 4).

<u>Chapter Errata</u>

Cor – correction of language

Page/Line	Original text	(type of correction) Corrected text
73	"Figure 3. Relative Percentage Activity (RPA) using idealized modelling framework; reverse streamline method; under binning scheme 1, for Piha, Whangamata, Pines (top row; left to right) …"	(Cor) "Figure 3. Relative Percentage Activity (RPA) using idealized modelling framework; reverse streamline method; under binning scheme 1, for Piha, Manu Bay, Whangamata, Pines (top row; left to right) …"

Journal of Coastal Research	SI	87	70-77	Coconut Creek, Florida	2019

A Comparison of Methods for Defining a Surf Break's Swell Corridor

Edward A. Atkin[†§*] and Dougal Greer[†]

[†]eCoast Marine Consulting and Research
Raglan, New Zealand

[§]University of Waikato
Hamilton, New Zealand

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Atkin, E.A. and Greer, D., 2019. A comparison of methods for defining a surf break's swell corridor. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand*. *Journal of Coastal Research*, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.

A swell corridor is the offshore extension of a surf break that waves travel through before reaching the surf break area. Establishing the location and characteristics of a swell corridor is imperative to making sustainable decisions regarding surfing resources. To date, there are no known published studies that consider how a swell corridor should be spatially and quantitatively defined. This study considers different numerical modelling and post processing approaches to constructing a surf break's swell corridor. The basis for defining the footprint of the swell corridor for each of the approaches is to simulate a range of wave conditions, and use streamlines to determine the origin of the swell. Methods consider streamlines that originate offshore and run landward and streamlines that run from a surf break to a point offshore, referred to as forward and reverse methods. These methods are jointly applied to both hindcast and idealized wave conditions. The collection of streamlines for a surf break are used to create maps of Relative Percentage Activity – a normalized count per spatial bin. The recommended method for the characterization and definition of a surf break's swell corridor is the full hindcast with reverse streamline method.

ADDITIONAL INDEX WORDS: *Surfing, resource management, streamline, wave climate, numerical model.*

INTRODUCTION

On a global scale, surf breaks are becoming increasingly recognized as coastal resources (Ball, 2015). As a result of numerous cases of surf break degradation worldwide, there has been an increased requirement for methods to enable protection (Nelsen *et al.*, 2013; Scarfe *et al.*, 2009). The New Zealand Coastal Policy Statement 2010 (NZCPS) identifies surf breaks as coastal resources and provides a physical definition of a surf break. One component of a surf break recognized by the NZCPS is a swell corridor - the region offshore from the surf break where ocean swell travels and transforms into a surfable wave. A swell corridor is essentially an offshore extension of a Surf Break Area (SBA; Atkin and Mead, 2017).

To date, the day to day management of surf breaks in Aotearoa New Zealand has been addressed at a regional level. The NZCPS observes an offshore jurisdictional range for authorities at a regional level as the edge of the Territorial Sea (TS), 12 nautical miles from land. The reality is that, in theory, a swell corridor can extend across an entire ocean basin.

Activities within a swell corridor have the potential to have adverse effects on a surf break's consistency and quality. An assessment of any activities therefore requires an understanding of the physical processes affecting a surf break, including any sheltering, focusing, or rotation of wave energy offshore of a surf break caused by bathymetric features (Scarfe *et al.*, 2009).

It is therefore important to define a surf break's swell corridor to enable effective management of the coastal resource. Despite discussion on the importance of swell corridors (Nelsen *et al.*, 2013; Scarfe *et al.*, 2009); contributions in grey literature (Atkin, Gunson, and Mead, 2015; Atkin and Mead, 2017); and, while surfing waves have been objectively defined (Hutt *et al.*, 2001; Mead and Black, 2001a,b,c; Walker 1972), to date, there are no published examples of methods for defining a surf break's swell corridor.

This research considers methods for defining a surf break's swell corridor. The advantages and disadvantages associated with each method are discussed. The study sites chosen for this research are described in Atkin *et al*. (2017; Figure 1) and are all located in Aotearoa New Zealand, namely: Aramoana and Whareakeake in Otago; Lyall Bay in Wellington; Manu Bay and Piha on the west coast of the Waikato and Auckland Regions, respectively; Whangamata on the Coromandel Peninsular; and Wainui Beach in Gisborne.

METHODS

The primary processing tool used in this study is the numerical model SWAN (Holthuijsen *et al.*, 2004). A nesting scheme of 5 levels was used to increase spatial resolution at the study sites, with grids spacings of 0.05°, 0.01°, 0.002°, 0.0004° and 0.00008° from levels 1 (national scale) to 5 (surf break scale). The spatial

DOI: 10.2112/SI87-007.1 received 28 August 2019; accepted in revision 6 September 2019.
*Corresponding author: e.atkin@ecoast.co.nz

extent of a Level 2 nest was defined so it encompassed the TS of Aotearoa New Zealand.

Data used to construct model bathymetry grids were compiled from the Global Bathymetric Chart of the Oceans (GEBCO; Becker *et al*., 2009), nautical charts, Shuttle Radar Topography Mission (Jarvis *et al*., 2008), and localized bathymetric surveys where available.

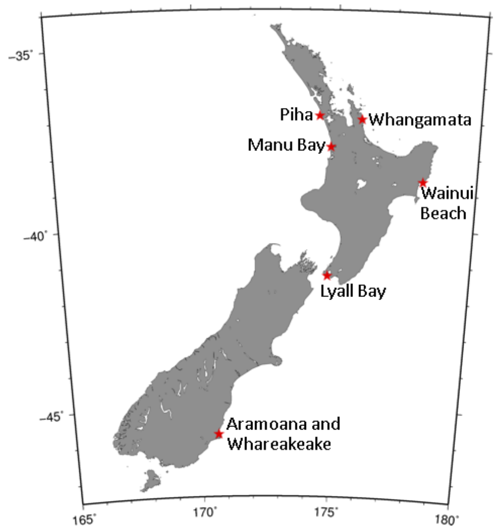


Figure 1. Map of Aotearoa New Zealand showing the location of the seven study sites.

Two modelling frameworks were undertaken. The first framework simulated 10 years of hind-casted, 2-dimensional wave spectra from the European Centre for Medium-Range Weather Forecast's ERA Interim 1°x1° resolution database (Berrisford *et al*., 2011); with, 10 m wind data sourced from the National Centers for Environmental Prediction's (NCEP) hourly global reanalysis model (Kalnay *et al*., 1996) with a spatial resolution of 0.312°x0.312°.

The second modelling framework, based on the earlier grey literature work of Atkin, Gunson, and Mead (2015); and Atkin and Mead (2017), simulated schematized wave boundary conditions with SWAN in stationary mode. The catalogue of wave conditions included wave directions (D_p) from 10° to 360° in 10° increments, peak period (T_p) from 7 s to 20 s in 1 s increments and significant wave heights (H_s) from 0.5 m to 11 m in 0.5 m increments. This provided a total of 11088 model cases.

Both hindcast and idealized conditions were simulated at a Aotearoa New Zealand scale (Level 1) and nested down to a surf break scale (Level 5); with a water level approximate to Mean Sea Level (MSL).

Model output (both hindcast and idealized) was filtered to retain only conditions that result in a wave height greater than or equal to a threshold within an SBA. Surfable wave height is both dependent on the surf break and skill or preferences of the surfer. Hutt *et al*. (2001) reported surfer skill levels in relation to wave heights as low as 0.3 m for top professional surfers. Other studies and literature state waves greater than 0.5 m are considered surfable (Atkin, Gunson, and Mead, 2015; Kimura *et al*., 2014; Ranasinghe *et al*., 2001; Walker, 1972). Mortensen *et al*., (2015) use a minimum significant wave height of 0.8 m in a study of surfing conditions conducted at Lyall Bay. Pattiaratchi *et al*. (1999) consider a minimum significant wave height of 1.5 m as a prerequisite for surfable waves, following the surfable criteria used by Dally (1990; 1.25 m and 1.5 m).

Given the range of reported minimum wave size (0.3-1.5 m), and the detail provided in the aforementioned studies, that the highest 10% of waves are more readily utilized by surfers (Dally, 1990) and, that there is a requirement to strike a balance between a conservative approach (See NZCPS) and implementable coastal management (*e.g.*, not choosing zero as a minimum wave height) a minimum H_s threshold of 0.75 m is used in this study. While the threshold used here is considered appropriate to each of the study sites, the minimum wave height threshold should be evaluated on a case by case basis.

The model output was further filtered to conditions that resulted in a period of 7 seconds or greater within an SBA. The period filter was included following initial tests with hindcast data where the inclusion of small period waves made the application of the streamline method used in this study unsuitable for processing due to confounding signals associated with local wind waves. There are surf breaks reliant on small period waves and previous surf science studies have considered wave periods of 6 seconds or greater (Mead *et al*., 2004); however, for the open coast locations study here, the threshold was deemed acceptable.

The paths of incident waves were described by determining a Forward Euler streamline, which is analogous to the ray tracing of a wave orthogonal, except that the streamline follows the vector field of modelled mean wave direction as a postprocessing step. Streamlines were described across consecutive grid levels. One parameter in the Euler streamline method is the step size for sequential streamline points. Increased step sizes resulted in larger errors. A compromise between realistic processing times and a requirement for accurate results, resulted in a step size of 10^{-1} of the computational model grid spacing.

For both sets of model output (hindcast and idealized), 2 sets of streamlines were undertaken: from offshore to onshore – termed forward streamline, and from onshore to offshore – reverse streamline, using the reciprocal direction of incident waves. In the case of reverse streamline the start locations were defined by 2 locations that demark the outer and longshore limits of the SBA. Forward streamlines began at discrete points, spaced at 0.005°, along the TS in the Level 2 grid. It is hypothesized these methods will produce different results, especially concerning processes around features such as islands.

The inclusion of idealized cases was regulated by checking either start (forward method) or end (reversed) streamline locations against the hindcast data. In both forward and reverse methods these points are offshore. In the forward case this is one of the discretized points on the TS, for the reverse case the point is defined by the intersect between TS and streamline. At this point wave statistics (H_s, T_p, and mean direction (D_m)) were extracted from the idealized datasets. A Percentage Occurrence (PO) for the idealized wave condition was determined using a time series extracted from the hindcast model output at the nearest grid node.

The PO method requires a binning scheme, with limits specified for H_s, T_p, and D_p, and a range of bin limits were tested. The following, incrementally narrower, binning schemes were tested:

(1) H_s +/- 0.25 m; T_p +/- 0.5 s; and, D_p +/- 5°
(2) H_s +/- 0.125 m; T_p +/- 0.25 s; and, D_p +/- 2.5°
(3) H_s +/- 0.0625 m; T_p +/- 0.125 s; and, D_p +/- 1.25°
(4) H_s +/- 0.0313 m; T_p +/- 0. 0625 s; and, D_p +/- 0.625°

The first binning scheme limits are half the size of the steps used to create the array of idealized boundary conditions. The limits of each subsequent binning scheme are reduced by half. The binning schemes are forthwith referred to as Scheme *n*, where *n* =1-4. Those streamlines associated with a PO of 0, a condition that never occurs within the modelled hindcast record, were discarded. Those with a positive PO were retained. For the hindcast, reverse streamline method all streamlines were retained following initial filtering (*i.e.*, conditions are real and greater than 0.75 m in the SBA). Streamline starting points were the same as described for the idealized case (2 locations on the SBA). In the forward streamline method (both hindcast and idealized), those streamlines that did not pass through the SBA in the Level 5 grid were discarded.

For each method, the collated streamlines spatially defined the footprint of a swell corridor. To evaluate the relative contribution of incident waves, a grid, with a spatial resolution of 0.002°x0.002°, was populated using the set of streamlines, whereby, if a streamline passes through a grid cell the count increased. The count on each bin was normalized to a common scale by dividing by the number of valid streamlines over all, and in the case of the forward streamline method, by the number of streamlines reaching the SBA during the conditions/timestep, providing a Relative Percentage Activity (RPA) per spatial bin.

RESULTS

All results are presented using a log scale to visualize the full range of RPA. Each figure includes the extent of the territorial sea and regional boundaries. Figure 2 presents the post-processed streamline results at Manu Bay for the 4 different binning schemes used in PO analysis for the reverse and forward streamline methods.

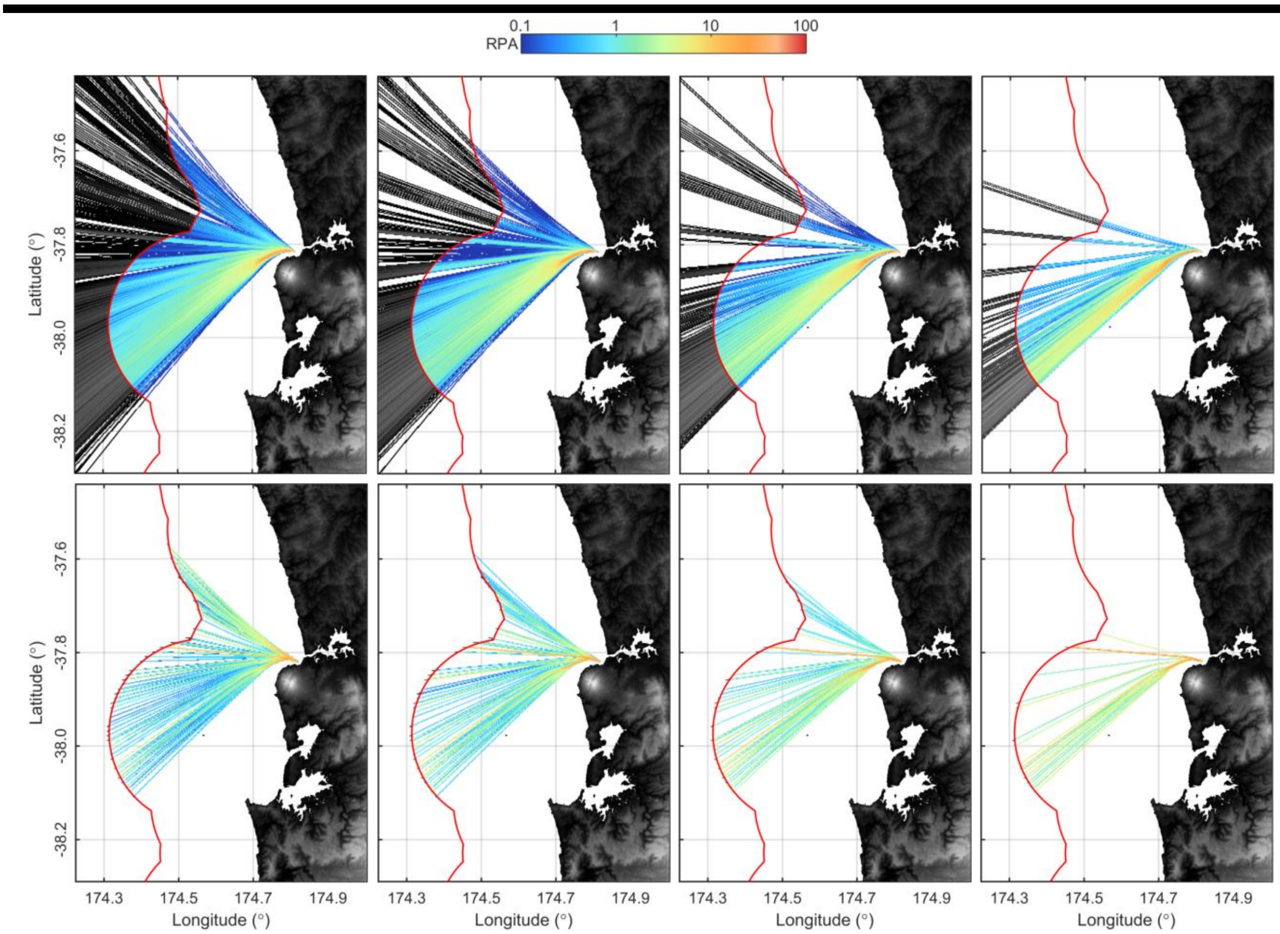


Figure 2. Relative Percentage Activity at Manu Bay: idealized; reverse (top) and forward (bottom); schemes 1 through 4 (left to right). Data outside the TS (red line) in greyscale. Across all binning schemes, the forward method provides low density coverage when compared to the reverse method.

As the wave statistic bins narrow from schemes 1 through 4 the number of streamlines that make up the swell corridor are reduced, as would be expected with stricter criterion for inclusion.

Figure 3 presents the swell corridors for all sites using the idealized model output and binning scheme 1 (most tolerant) and constructed using the reverse method. The grouping of streamlines as they move away from the SBA is clearly evident. The grouping artifact results in significant data gaps in the footprint defined by the streamlines.

At Pines, Whangamata and Lyall Bay the swell corridor crosses the regional boundary line. The data presented for Lyall Bay indicate that streamlines leave the SBA, travel through the Cook Strait and terminate in the Tasman Sea. Numerous streamlines exit the SBA to the south and head east close to the TS, which appear spurious.

Figure 4 compares the post-processed streamline results at Manu Bay for the hindcast data approach using forward and reverse streamline methods. Qualitatively, both methods provide similar results in terms of the area occupied by the collection of streamlines and the spatial RPA variability. Both methods provide almost complete coverage. However, the method of discretizing the polyline defined by the extend of the TS, which is used for the starting points of streamlines, results in a streaky and noisy appearance in the forward streamline method, this is most notable close to the TS. The forward streamline method also produces a number of valid streamlines outside of the TS. Similar results were found for Piha. These results stem from streamlines starting on the discretized TS on the western most part of the Taranaki Region to the south (see Figure 4).

One reason why the more complex and computationally demanding forward streamline method was included in this study was to consider the effects of wave shadowing from islands. Figure 5 presents RPA values at Whangamata from hindcast data using forward and reverse streamline methods.

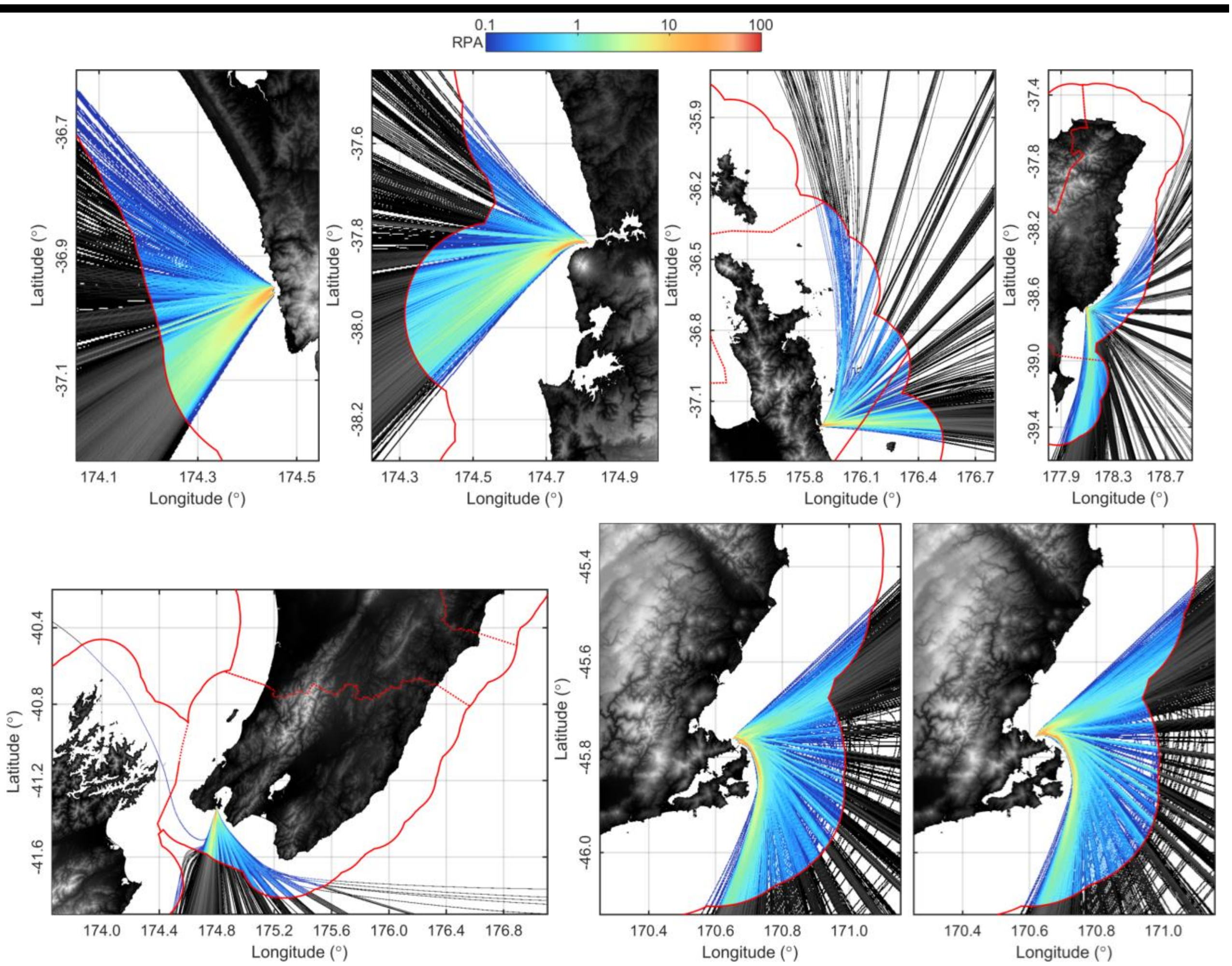


Figure 3. Relative Percentage Activity (RPA) using idealized modelling framework; reverse streamline method; under binning scheme 1, for Piha, Whangamata, Pines (top row; left to right), Lyall Bay, Aramoana and Whareakeake (bottom row; left to right). Solid red line: Territorial Sea. Dashed redline: regional authority boundaries.

Apparent in both methods is an elongate tear drop shape area of zero RPA associated with the Alderman Islands (~36.95°S/~176.1°E). The feature is both longer and wider in the forward method example and the width of the zero RPA zone around the islands is wider as well. This region of the swell corridor appears to be made up of significantly fewer streamlines using the forward method compared to the reverse. The feature does not represent a true shadow zone but highlights an area where swell may pass through but does not contribute to the surfable wave climate at Whangamata.

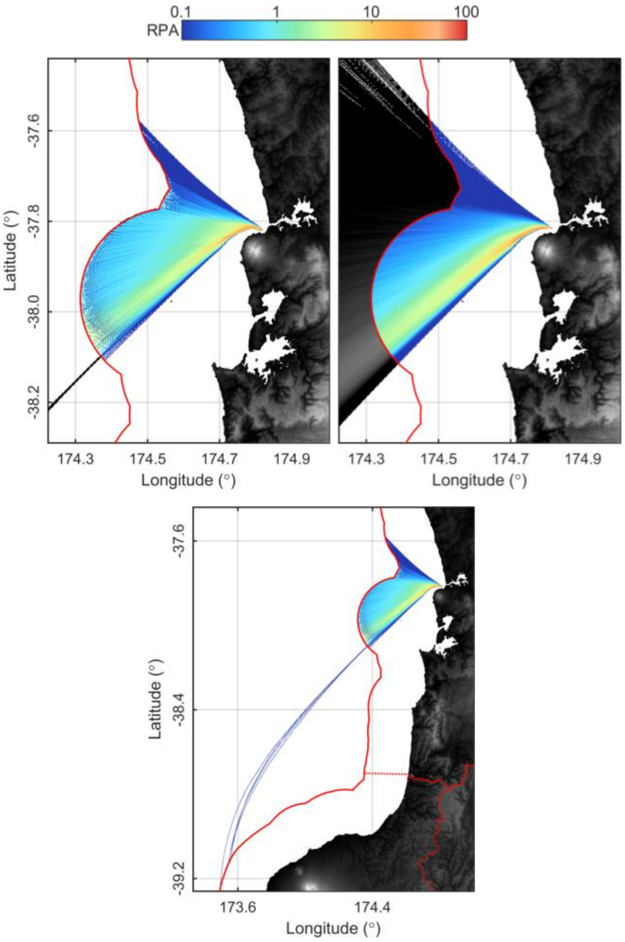


Figure 4. Relative Percentage Activity (RPA) from streamlines for Manu Bay: hindcast: forward (left top), reverse (right top), and extended view (bottom) for forward streamline methods. The extended view shows forward method streamlines originating on the TS boundary in Taranaki and terminating in the SBA of Manu Bay in the Waikato.

The forward method shows streamlines outside the TS. Unlike those observed for Manu Bay (Figure 4), these are proximal to the study site and adjacent to the swell corridor itself, and in this case head out of the TS only to come back in to terminate in the SBA. Of note in the reverse streamline method is a single streamline terminating north of Great Barrier Island. The termination location is coincident with the edge of the level 2 model domain – a limitation put in place during processing. The occurrence of surfable conditions at Whangamata originating from this area are intuitively doubtful.

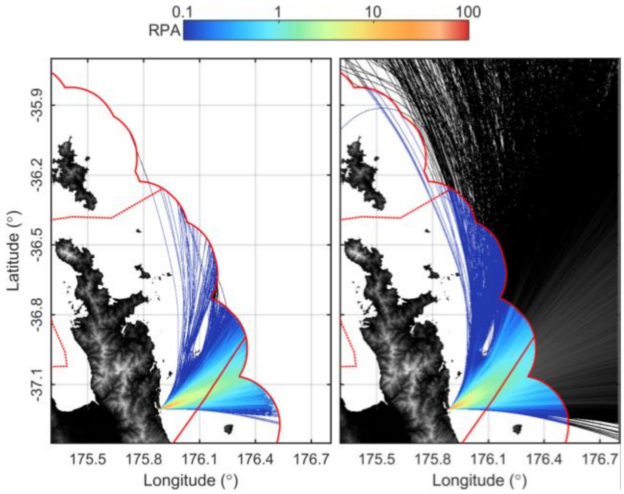


Figure 5. RPA Whangamata: hindcast: forward (left) and reverse (right) streamline method. Elongate teardrop shape associated with the Alderman Islands (~36.95°S/~176.1°E); streamlines outside the TS in the forward (left) streamline method; and, the single streamline terminating north of Great Barrier Island in the reverse (right) streamline method.

Figure 6 presents RPA results for all sites using the hindcast data and the reverse streamline method. There are a number of notable observations. There is a substantial footprint established through the Cook Strait and out into the Tasman for the Lyall Bay case. The swell corridor at Pines is comparatively wide, covering some ~85° in the near field, and much higher further away. The RPA hotspot of the swell corridor at Whangamata is bisected by the Waikato - Bay of Plenty regional boundary.

DISCUSSION

The use of hindcasted, spectral data in a reverse streamline method is considered the most appropriate method of those presented here. It provides the most coverage, allows for an evaluation beyond the territorial sea, and is not restricted by a binning regime.

Spurious Streamlines

Apparent in all methods, but not all sites, are spurious streamlines that look out of place relative to the bulk of data, and/or follow routes that are not intuitively associated with wave propagation. Figure 7 provides an example of one such streamline from Pines in Gisborne using the hindcast, forward method. Figure 7 compares mean wave direction, peak wave direction and direction of energy transfer; and swell wave height. The data shows there are conflicting swells offshore of Pines at this point in time. A southerly swell component is apparent in the lower left half of each plot, and the streamline, starting on the TS, clearly heads south with the northly swell coming around East Cape.

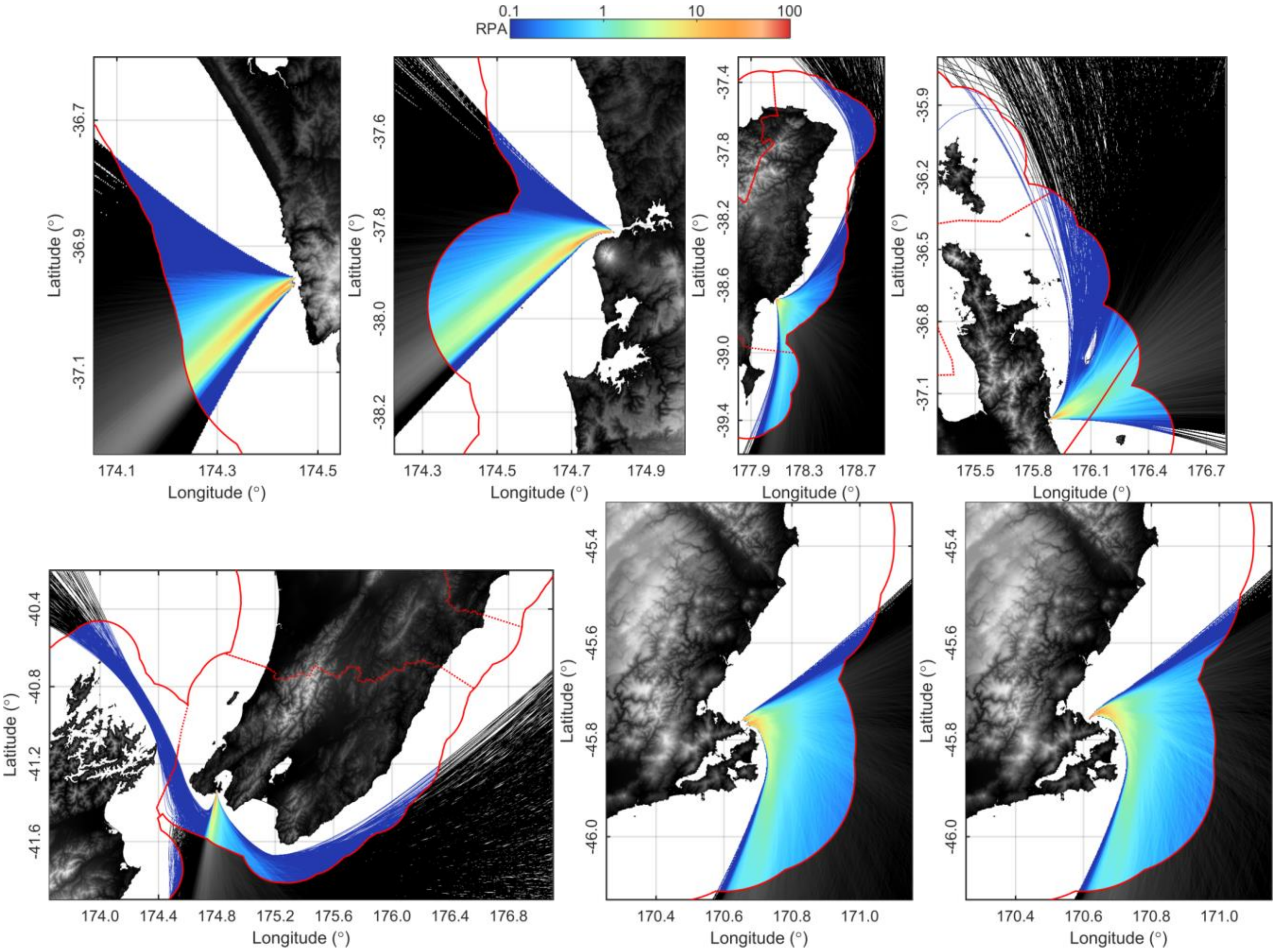


Figure 6. RPA from hindcast modelling framework; reverse streamline method for Piha, Manu Bay, Whangamata, Pines (top row; left to right), Lyall Bay, Aramoana and Whareakeake (bottom row; left to right).

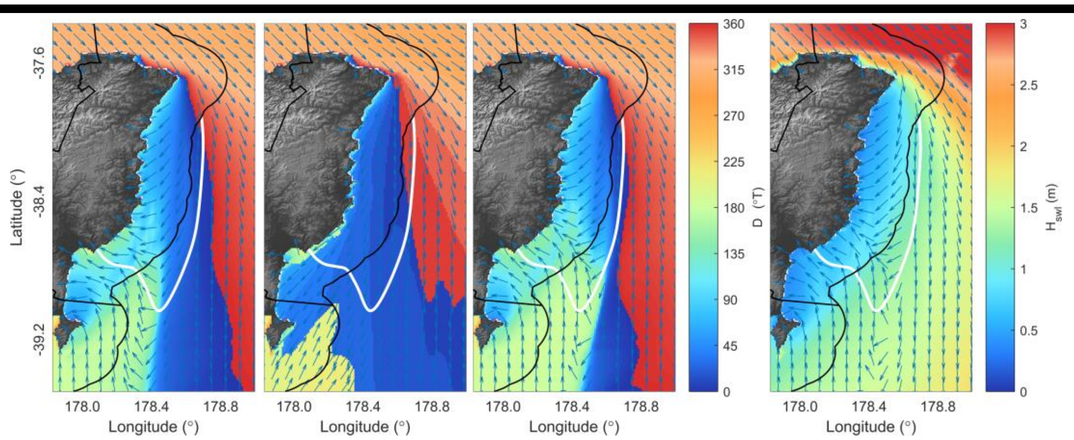


Figure 7. Single forward streamline (white line) from hindcast data for Pines overlaid on mean direction (left), peak direction (left-middle), direction of energy transfer (right-middle) and swell wave height (right), with regional boundary and territorial sea (black line).

Idealized Method

The forward streamline method using idealized data has yielded results that are not consistent with the other 3 methods (idealized reverse; hindcast reverse; hindcast forward). The low streamline density, even when considering binning scheme 1 (most tolerant), does not present a clear picture of the swell corridor.

An advantage of using idealized conditions is the uniformity of wave directions used to calculate streamlines due to the monochromatic wave conditions. This is useful for the most part, however at complex sites such as Lyall Bay, converging wave conditions can occur leading to potentially spurious streamlines.

The relative scarcity of streamlines using idealized methods could be reduced by using smaller increments when defining idealized conditions. However, this also comes at the expense of increased computational time.

Hindcast Method

Reverse and forward hindcast show consistent general patterns in terms of the area occupied and RPA hotspots. The use of hindcast data provides significantly more coverage when compared to using idealized boundary conditions. A more complete picture would likely be achieved by simulating a longer hindcast subset. A worthwhile exercise would be to evaluate the sensitivity of a swell corridor to hindcast length.

Forward vs Reverse

For the reverse streamline method only, a PO threshold greater than 0 needs to be satisfied. For the forward streamline, in addition to the PO being exceeded, the streamline must transit through or terminate in the SBA. The forward streamline start points are determined by discretizing the TS. Reducing the spacing between points and increasing the number of start points would potentially increase the number of streamlines that satisfy inclusion conditions. This would however increase computational time.

Forward streamline methods presented here do not provide any information outside of the territorial sea. This could be addressed by running forward streamlines from the outer most grid limits, or from an alternative maritime boundary, such as the Contiguous Zone or Exclusive Economic Zone.

The assumption made in streamline methods are that the delivery of wave energy to an SBA occurs along the streamline. In reality, the wave energy being delivered to an SBA is not from a single point, but from a wider, along crest window. The width of this window would increase in distance from an SBA. An improved method would take this along crest spatial requirement in to account. To date, Atkin, Gunson, and Mead, (2015); and Atkin and Mead (2017) have used buffer zones to account for numerical model shortcomings.

There are alternative model output parameters that could be employed in the method described here. These include using wave height associated with a high period threshold (a swell component). Here we have used the mean direction for defining a streamline, which can be associated with smaller period waves. However, using peak period to initialize the model rather than mean period, can introduce sharp discontinuities in direction values across a model domain which is not ideal for streamlining.

The methodology used here has not considered direction within an SBA. For the purpose of this study, wave height and period are the limiting factors in terms of surfability. The limiting factors for surfability should be assessed on a case by case basis, and there will be locations where wave heights of less than 0.75 m and/or period of less than 7 seconds result in surfable conditions.

There are a number of factors that have not been accounted for in this primary study. For example, the model has not been calibrated with field data. This step would certainly be required for an investigation of a specific surf break. There are also limitations to practicable timescales for execution, and the vast array of potential conditions can create long computation times. The effects of tide, which influences refraction and diffraction processes, were not included. Lastly, a higher order method for defining a stream line, such as Runge-Kutta (or "RK"), may yield more accurate results, especially given the nonlinear nature of wave orthogonals as they refract in coastal waters. However, given the high-resolution step size used in this study, the (linear) Forward Euler method is considered sufficient.

CONCLUSIONS

The results presented here have shown that the grey-literature method used in Atkin, Gunson, and Mead (2015); and Atkin and Mead (2017) can be improved, in terms of coverage and reliability by using hindcast data as a basis for streamlining. The decision of which method would be used would depend on the application. For example, the idealized approach is less sophisticated and less computationally demanding and has been used to good effect for the development of preliminary assessment and management tools; yet there is no harm in using the hindcast method for this reason. A site-specific investigation would certainly warrant the hindcast method combined with a calibration component.

The field of surf science is relatively young. As far as the authors are aware, there are no published works to date concerning swell corridors, so this work is a significant advancement in this field. The limitations of this study provide the framework for further studies and define a focus on comparing the relevance of numerical model calibration and longer hindcast datasets, testing streamline start locations, consideration for along crest energy requirements and quality control methods. Computational time will always be a limitation. There is a clear need to strike a balance between functional outputs and reasonable computational demand.

The data produced with the methods here can be used to develop resource management tools for decision makers. For example, polygons around a collection of streamlines can be constructed allowing spatial assessments to be made. Polygons can be divided based on associated occurrence values, or percent activity to produce a main swell corridor and buffer zones (*e.g.*, Atkin and Mead, 2017).

Individual streamlines that contribute to the swell corridor are observed to traverse regional boundaries. This indicates that the management of the area occupied by a surf break's swell corridor may require collaboration between regional level authorities.

ACKNOWLEDGMENTS

The authors would like to thank Aotearoa New Zealand's Ministry of Business Innovation and Employment (MBIE) for funding of this research, contract UOWX1502; and, Dr Shaw

Mead and Laurent Lebreton for their contributions in developing original methodologies.

LITERATURE CITED

Atkin, E.A.; Gunson, M., and Mead, S.T., 2014. *Regionally significant surf breaks in the greater Wellington region.* Raglan, New Zealand: eCoast Marine Consulting and Research, 93p.

Atkin, E.A. and Mead, S.T., 2017. *Surf breaks of regional significance in the Waikato region.* Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research, 75p.

Atkin, E.A.; Mead, S.T.; Bryan, K.; Hume, T., and Waiti, J., 2017. Remote sensing, classification and management guidelines for surf breaks of national and regional significance. *Proceedings of the 23th Australasian Coasts and Ports Conference* (Cairns, Australia).

Ball, S., 2015. The green room: A surfing-conscious approach to coastal and marine management. *UCLA Journal of Environmental Law and Policy*, 33 (2).

Becker, J.J.; Sandwell, D.T.; Smith, W.H.F.; Braud, J.; Binder, B.; Depner, J.; Fabre, D.; Factor, J.; Ingalls, S.; Kim, S-H.; Ladner, R.; Marks, K.; Nelson, S.; Pharaoh, A.; Trimmer, R.; Von Rosenberg, J.; Wallace, G., and Weatherall, P., 2009. Global bathymetry and elevation data at 30 arc seconds resolution: SRTM30_PLUS. *Marine Geodesy*, 32(4), 355-371.

Berrisford, P.; Dee, D.P.; Poli, P.; Brugge, R.; Fielding, K.; Fuentes, M.; Kållberg, P.W.; Kobayashi, S.; Uppala, S., and Simmons, A., 2011. *ERA Report series: The ERA-interim archive v2.* Berkshire, United Kingdom: European Centre for Medium-Range Weather Forecasts.

Holthuijsen, L.H.; Booij, N.; Ris, R.C.; Haagsma, I.J.G.; Kieftenburg, A.T.T.M.; Kriezi, E.E.; Zijelma, M., and van der Westhyusen, A.J., 2004. *SWAN User Manual Cycle III version 40.41.* Delft, the Netherlands: Delft University of Technology, 27p.

Hutt, J.A.; Black, K.P., and Mead, S.T., 2001. Classification of surf breaks in relation to surfing skill. *Journal of Coastal Research,* Special Issue No. 29, 66-81.

Jarvis, A.; Reuter, H.; Nelson, A., and Guevara, E., 2008. *Hole-filled seamless SRTM data v4*. Colombia: International Centre for Tropical Agriculture (CIAT), 9p.

Kalnay, E.; Kanamitsu, M.; Kistler, R.; Collins, W.; Deaven, D.; Gandin, L.; Iredell, M.; Saha, S.; White, G.; Woollen, J.; Zhu, Y.; Leetmaa, A.; Reynolds, R.; Chelliah, M..; Ebisuzaki, W.; Higgins, W.; Janowiak, J.; Mo, K.C.; Ropelewski, C.; Wang, J.; Jenne, R., and Joseph., D., 1996. The NCEP/NCAR 40-year reanalysis project. *Bulletin of the American Meteorological Society*, 77, 437-470.

Mead, S.T. and Black, K.P., 2001a. Field studies leading to the bathymetric classification of world-class surfing breaks. *In:* Black, K.P. (ed.) *Natural and artificial reefs for surfing and coastal protection, Journal of Coastal Research*, Special Issue No. 29, pp. 5-21.

Mead, S.T. and Black, K.P., 2001b. Functional component combinations controlling surfing quality at world-class surfing breaks. *In:* Black, K.P. (ed.) *Natural and artificial reefs for surfing and coastal protection*, *Journal of Coastal Research*, Special Issue No. 29, pp. 22-32.

Mead, S.T. and Black, K.P., 2001c. Predicting the breaking intensity of surfing waves. *In:* Black, K.P. (ed.) *Natural and artificial reefs for surfing and coastal protection, Journal of Coastal Research*, Special Issue No. 29, pp. 51-65.

Mead, S.T.; Scarfe, B.; Blenkinsopp, C., and Black, K., 2004. *Feasibility and preliminary design study for an artificial surfing reef at Mahomet's Beach, Geraldton, Western Australia.* Geraldton, Western Australia: Geraldton Boardriders Club, *Technical Report.*

Mortensen, S.; Tree, M., and Tuckey, B., 2015. *Wellington airport runway extension surf break impact assessment: Numerical modelling, preliminary mitigation investigations and feasibility study.* Auckland, New Zealand: DHI Water and Environment Ltd., 99p.

Nelsen, C.; Cummins, A., and Tagholm H., 2013. Paradise lost: Threatened waves and the need for global surf protection. *Journal of Coastal Research*, Special Issue 65 (1) - ICS, 904-908.

Pattiaratchi, C.B.; Masselink, G., and Hurst, P., 1999. Surfability of the Perth metropolitan coastline: An assessment. *Proceedings of the 14th Australasian Coasts and Ports Conference* (Perth, Australia), pp. 464-469.

Ranasinghe, R.; Hacking, N., and Evans, P., 2001. *Multi-functional artificial surf breaks: A review.* Parramatta, Australia: Centre for Natural Resources, NSW Department of Land and Water, 53p.

Scarfe, B.E.; Healy, T.R.; Rennie, H.G., and Mead, S.T., 2009. Sustainable management of surfing breaks: Case studies and recommendations. *Journal of Coastal Research*, 25(3), 684–703.

Walker, J.R.; Palmer R.Q., and Kukea J.K., 1972. Recreational surfing on Hawaiian reefs. *Proceedings of 13th Coastal Engineering Conference, 1972,* pp. 2609-2628.

7 Investigations of Offshore Wave Preconditioning

Publication details:

Atkin, E.A., Mead, S.T., and Phillips, D., 2019. Investigations of Offshore Wave Preconditioning. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 78–90. Coconut Creek (Florida), ISSN 0749-0208.

The publisher has been granted permission to reproduce this article in the published format. Pagination of the reproduced article is carried over from publication and not synchronised with the main body of this thesis. Page references to any errata are relevant to the publication.

During stakeholder engagement (Chapter 3) the role of offshore features in contributing to surfing wave quality was highlighted at the study sites of Aramoana, Pines and Whareakeake. Understanding the breadth and range of offshore features that impact on a surf break is particularly important from a management perspective. The identification of case studies used in this chapter was based on literature review of works relating to surf break mechanics and supplemented by the authors experience and knowledge of surfing waves globally. This work provides the first published compilation of the geometry of natural preconditioning features and conceived the notion of a spectrum preconditioners, from disruptive to focusing. The research established a foundation for further investigation of offshore preconditioning, while emphasising the importance of knowing and understanding the configuration and role of features within a surf break's swell corridor for effective surfing resource management.

Chapter Errata

Cor – correction of language

Page/Line	Original text	(type of correction) Corrected text
81/11 & 14	"Halfmoon Bay…"	(Cor) "Half Moon Bay…"
81	"Figure 3. Top: multibeam bathymetry offshore of Pillar Point, Halfmoon Bay…"	(Cor) "Figure 3. Top: multibeam bathymetry offshore of Pillar Point, Half Moon Bay…"

Journal of Coastal Research	SI	87	78–90	Coconut Creek, Florida	2019

Investigations of Offshore Wave Preconditioning

Edward A. Atkin[†‡*], Shaw T. Mead[†§], and David Phillips[†§]

[†]eCoast Marine Consulting and Research
Raglan, New Zealand

[‡]University of Waikato
Hamilton, New Zealand

[§]Unitec Institute of Technology
Auckland, New Zealand

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Atkin, E.A.; Mead, S.T., and Phillips, D., 2019. Investigations of offshore wave preconditioning. *In*: Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 78–90. Coconut Creek (Florida), ISSN 0749-0208.

The way in which a wave breaks is largely a function of the path wave orthogonals and the bathymetry that wave orbitals encounter as the wave propagates shoreward. This effect is commonly referred to in surf science literature as preconditioning and occurs at a range of scales. This work considers seabed features that do not cause wave breaking but influence the way in which they break. An assessment first quantifies the dimensions of a number of known wave preconditioning features, and then involves iterative numerical model simulations of heuristic seabed features. The impact of an offshore feature is descried in terms of the wave propagation in the lee of the feature and breaking patterns, or surf zone plan-shape, near the shoreline. It is proposed that offshore features be considered as either disruptive or focus preconditioners. The former results in complex and chaotic interference patterns resulting in multiple peaks at the shoreline, with the latter creating a more singular or defined peak with less widespread disruption. A key component for surfing wave quality to be influenced by offshore preconditioning is the establishment of longshore wave height gradients, which are often associated with the bifurcation, or "snapping" of wave crests. The degree to which a feature sets up longshore wave height gradients and bifurcates wave crests is shown to be influenced by the size of the preconditioning feature relative to the incident wave conditions.

ADDITIONAL INDEX WORDS: *Surfing, modeling, surf break, focussing, bathymetry.*

INTRODUCTION

The effects of bathymetric variations on gravity wave propagation are well documented. Refraction and diffraction result in energy shifts, manifested in wave height gradients from focussing or de-focussing of wave orthogonals. The consequent effects of these processes are evident in the breaking wave patterns at the coast. The activity of surfing is facilitated by relatively unique and rare instances of breaking patterns at the coast that can be both complex and chaotic. In the context of existing surf science literature, this offshore modification process prior to breaking is defined as wave preconditioning (Mead and Black, 2001a, b).

In order to sustainably manage surf breaks as resources, it is imperative to have an understanding of the geomorphological components that contribute to the breaking of waves that are conducive to surfing. Preconditioning of waves for surf breaks occurs in the 'swell-corridor', that is "the region offshore of a surf break where ocean swell travels and transforms to a 'surfable wave" (Department of Conservation, 2010). This is colloquially referred to as the 'swell window' in other countries, such as Australia.

West (2002) and West *et al.* (2003) simulated wave propagation over a designed submerged feature with a range of lengths, widths and depths superimposed on a 1:20 slope with a 1 m wave at 8 s. West concluded that a feature with a height:width:length ratio smaller than 1.5:10:40 m would not cause sufficient focussing to change surfing conditions. West surmised that wave peel angle, the angle between the unbroken wave crest and line of the breaking part of a wave (Hutt *et al.*, 2001; Walker *et al.*, 1972), reduced with increasing distance between the offshore toe and shoreline. However, the results showed that where peel angles are conducive to surfing, the feature is inside the surf zone and breaking is initiated on the feature. In this case the feature is not exclusively performing a preconditioning role.

Mead *et al.* (2003) progressed the work of Mead and Black (2001b), which considered the scale of the focus components, by taking a broader approach. They considered how wave focussing occurs on very large scales on the continental shelf affecting large areas of the coast, through to small-scale surf break specific focussing that enhances wave quality. Consequently, the scale of wave focussing can affect wave height gradients along large stretches of coast or be fundamental local components of surf breaks, respectively.

Atkin *et al.* (2017) studied seven surf breaks in Aotearoa New Zealand. One of which was Aramoana Spit, a Surf Break of National Significance (Department of Conservation, 2010). This surf break is a sand bottom beach break that is reliant on wave preconditioning that involves multiple seabed features that modify incident wave crests (Kilpatrick, 2005; Mead and Atkin, 2019; Scarfe *et al.*, 2009). The beach is in the lee of: the terminal

DOI: 10.2112/SI87-008.1 received 28 August 2019; accepted in revision 6 September 2019.
*Corresponding author: e.atkin@ecoast.co.nz

lobe of an ebb tidal delta that extends from Taiaroa Head; the associated channel and channel margins; and, a dredge spoil disposal ground. The ebb tidal delta has been shown to focus waves (*e.g.*, Mead and Atkin, 2019), and the disposal ground can induce further focussing and bifurcation of wave crests, but also, at times break the incident wave crests. Aramoana is known for its hollow and powerful waves produced from "wedging peaks". Kilpatrick (2005) and Scarfe *et al.* (2009) have both shown that there are no functional components (Mead and Black, 2001b) or other prominent bathymetric features in the nearshore zone at Aramoana that would produce breaking waves conducive to surfing. With little to no discontinuities in the direction of isobaths in the nearshore, pre-conditioning of waves is required to set up wave focussing, alongshore wave height gradients, wave-wave interactions and/or bifurcation (splitting) of wave crests.

Whilst the processes at Aramoana are relatively well understood as a result of potential modifications to the surf break requiring a management strategy (Mead and Atkin, 2019), there is limited information available regarding the size, extent and configuration of offshore focussing features that are conducive to surfable conditions, and no information regarding design parameters should a feature require recreating, preserving or maintaining.

This research considers examples of offshore features in a surf break context as a basis to quantify the size, shape, offshore location and positioning of natural offshore submerged structures, with the aim of extending our understanding of elements of offshore focussing features. Existing investigations concerning wave offshore preconditioning have been largely focussed on individual study sites. Here a review of existing literature is combined with evaluations of previously unstudied sites, and heuristic model simulations.

METHODS

Measurements of cross shore length, longshore width, shoreline to foot and shoreline to toe distance, inshore and offshore depths, and feature top and offshore gradients were undertaken to construct a database of the characteristics of offshore preconditioning features. The global locations of the sites are shown in Figure 1 and listed in Table 1.

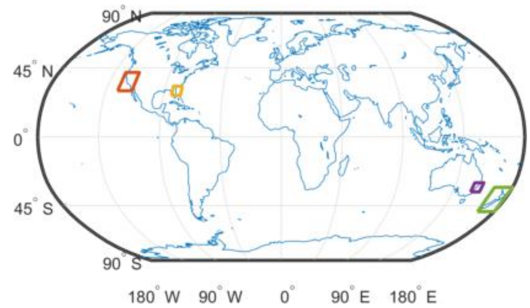


Figure 1. Global locations of surf breaks with known offshore preconditioning features used in this study, which includes sites in California, US (Orange), Florida, US (Yellow), New South Wales, Aus. (Purple) and Aotearoa New Zealand (Green).

Table 1. *Study site information. Note, some surf breaks are attributed multiple/different names that are not included here. See Atkin et al. (2019) and references therein for Surf Break Type descriptions.*

Name	State	Country	Surf Break Type
Aramoana	Otago	Aotearoa New Zealand	Beach
Atlantic Beach	Florida	United States of America	Beach
Cronulla	New South Wales	Australia	Beach
Matakana Island	Bay of Plenty	Aotearoa New Zealand	Beach
Mavericks	California	United States of America	Reef
Midway	Gisborne	Aotearoa New Zealand	Beach
Newport Beach	California	United States of America	Beach
North Narrabeen	New South Wales	Australia	Beach
Ocean Beach	California	United States of America	Beach
Rarotoka Island	Southland	Aotearoa New Zealand	Reef
The Peak	New South Wales	Australia	Beach

Measurements were made from nautical charts and existing bathymetric data. The notional separation of identified features from the ambient bathymetry was undertaken by identifying discontinuities in isobaths from the adjacent seafloor.

To consider the importance of various characteristics, phase resolving numerical simulations of monochromatic incident wave conditions were undertaken. The model bathymetry, a 400 x 400 cell domain using a 10 m cell spacing, largely consists of a planar surface with a 1:100 slope, which is broadly representative of Aotearoa New Zealand gradients, but may be flatter than natural slopes in Australia or Hawaii. Slopes flatter than 1:100 resulted in wave breaking on the feature in most simulations. The offshore depth is 36.2 m, with the first 10 offshore cells having no slope. The 30 cells at the shoreward end have a slope of 1:50 to synthesize a beach. Previous configurations used 15-20 cells; however, the width of the surf zone was too narrow to discern notable change with practical output graphics. This bathymetry, along with sponge type cross shore boundaries, resulted in a dissipative model environment, reducing the effects of reflections.

The planar bathymetry was modified to incorporate a pilot preconditioning feature loosely configured from the mean dimensions of the characterisation database (Figure 2). Simulations included incremental changes to the seabed feature and its positioning and are detailed in Table 2.

The boundary condition used in all simulations was a 0.65 m amplitude wave with a 14 second period and an angle of incidence perpendicular to the shoreline (0°). These conditions were considered a generic, baseline surf condition. To allow the model to stabilize, simulations were run for 3 times the number of time steps required for the initial wave front to reach the shore. A characteristic surf zone for each case was established by accumulating the locations where wave breaking occurred in the

4.5 minutes of real time prior to the presented time step – which provided a comprehensive depiction of the surf zone.

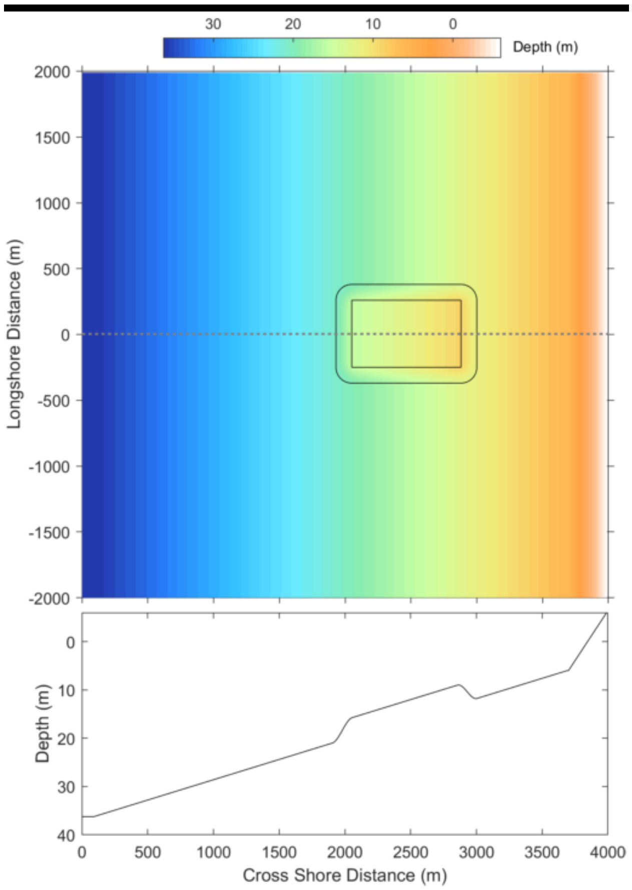


Figure 2. Top: Bathymetry of integrated pilot feature, demarked with black lines, and profile location in grey dotted line. Bottom: Depth profile.

Table 2. *Numerical model simulation cases and feature volumes in Mm³ (below). Cases highlighted in grey are identical to the Pilot case. Modification/iterations are changes to the pilot feature. Unless stated all characteristics remain the same as the pilot case.*

Characteristic	Iteration					
Distance of feature toe from shore (m)	770	970	1370	1770	2170	2570
	2.37	2.37	2.37	2.37	2.37	2.37
Height deducted from pilot (m)	0.5	1.0	1.5	2.0	2.5	3.0
	2.02	1.64	1.33	1.01	0.74	0.46
Inshore/offshore longshore width of feature (m)	120	320	520	720	920	1120
	0.85	1.61	2.37	3.13	3.89	4.65
Offshore Width of feature only (m)	120	320	520	720	920	1120
	1.63	2.01	2.37	2.77	3.15	3.53
Scale factor for length & width	0.5	1.5	2	2.5	3	3.5
	8.21	1.21	0.76	0.54	0.42	0.34
Transition from feature crest to seabed (°)	0	30	60	90	120	150
	1.69	2.37	3.13	3.98	4.91	5.92

RESULTS

Study Sites

Aramoana, Bay of Plenty, NZ

The ebb tidal delta shoals to ~7.7 m below Chart Datum (CD) from 16.5 m above the offshore seabed and 9.5 m above the inshore (LINZ, 2018). The inshore toe of the terminal lobe is 2,250 m from the shoreline at Aramoana. Considering just the terminal lobe, the feature is 975 m wide (shore parallel relative to Spit Beach) and 760 m long (shore normal). The terminal lobe is rounded at the northern end and is best described as semi-elliptical. The chosen subsection has a footprint of 0.58 km². The approximate volume of the feature considered here is 7 Mm³.

Atlantic Beach, Florida, USA

At Atlantic Beach in Florida, USA. on the south side of the heavily modified entrance to the St. Johns River, is a marginal shoal with a distinct north-north-east protrusion. The feature is relatively deep, yet numerical models show that focussing by the delta forms waves that are 1.5 times larger than waves to the south (Mead *et al.*, 2003). A focus was identified by Scarfe *et al.* (2003) as one of nine micro-scale components (Mead and Black 2001b) that make up the surf break at Atlantic Beach, which is colloquially known as 'The Mayport Poles' or 'The Poles'. The feature is 2.3 km from Atlantic Beach, the shore normal length is 1500 m, longshore width 2400 m in the inshore and 600 m offshore. The approximate footprint is 2.3 km². Taking a height over the ambient bathymetry of ~3.5 m the volume is calculated as ~8 Mm³.

Cronulla, NSW, Australia (The "sand slug")

At Cronulla Beach, an Australian surf reserve in New South Wales, Pitt (2010) proposed the deposition of clean dredge spoil (sand). The original proposal considered 24,000 m³ in a mound 50 m wide at the inshore end, 200 m from the shoreline, extending 400 m and tapering to 10 m at the offshore end. This was to be deposited between the 4 m and 11 m isobaths (CD). The mound was to be 9 m deep at the offshore end, shoaling to 2 m at the nearshore.

Pitt (2012) reported that 50,000 m³ of spoil from dredging operations of Port Hacking navigation channels was deposited at North Cronulla. The material was deposited 200 m to 500 m offshore in 4 to 8 m CD. The disposal area was 125 m and 100 m wide at the inshore and offshore ends respectively. An even deposition of 2 m within this area, as specified, would result in 45,000 m³. Following completion of the disposal, Pitt (2012) reported improved surf conditions and beach nourishment with the eventual dispersal of the sand feature.

Matakana Island, Bay of Plenty, NZ

Located in the Bay of Plenty of the North Island of Aotearoa New Zealand, Matakana Island is also known for hollow, peaky, barrelling A-frames waves. These waves are associated with the ebb tidal delta at the entrance to Tauranga Harbour. Mead *et al.*, (2003) note that it is the wave interference patterns caused by refraction over the ebb tidal delta that culminate in waves conducive to surfing. The 10 m (CD) isobath marks the edge of the navigation channel and extends 3 km offshore giving shape to the delta (LINZ, 2015). To the northwest the 10 m contour moves closer to the shoreline at ~1.3 km, where it remains steady for the length of Matakana Island. The feature is estimated as having a shore normal length of 1.7 km, an inshore longshore width of 2.4 km and is triangular in shape so the offshore width is taken as 0. The estimated footprint is 2 km^2. A difference of 4 metres between the surrounding bathymetry and the feature results in a volume of ~8 Mm^3. The inshore gradient of the delta (10 m to 6 m contour) is 1:320, the seaward facing gradient is 1:250.

Mavericks, California, USA

A renowned big wave surfing location, Mavericks is located at the northern end of Halfmoon Bay, California, US. The size of the preconditioning component at Mavericks is relatively large. Figure 3 presents multibeam bathymetry data (Cochrane, *et al.*, 2014) around Pillar Point at the northern end of Halfmoon Bay. A cross-section taken east to west through the preconditioning feature shows variable bathymetry associated with large fissures. The data was smoothed using a moving average and is interpreted here as two sections prior to the surfing area with distinct gradients.

The lower, offshore section has a shallower gradient of ~1:90. The inshore section is steeper at ~1:12 and orthogonal seabed gradients of this magnitude are predicted to produce “extreme” breaking intensities (Mead and Black, 2001c), which is a term synonymous with the surfing waves of Mavericks. For this study, the offshore section will be considered as the preconditioning feature, and depicted as rectangular. The inshore and offshore depths are ~21 and 26 m below ~CD/LAT, respectively and separated by ~660 m horizontally, with a width of 350 m. The ambient depths, on the southern side are ~28 m and 31 m. The approximate volume of the subsection being considered is 1.4 Mm^3. The toe is 400 m from the surfing area, which is being taken as the shoreline in this case.

Newport Beach, California, USA

One of the earliest references to the preconditioning of waves in relation to surfing wave conditions is Mesa (1996), who conducted a monitoring program between 1991 and 1995 to track an anthropogenic berm consisting of 0.98 Mm^3 of littoral material at Newport Beach, California, USA. The berm migrated shoreward over the study period at a rate of 30 m/yr. The feature reportedly enhanced surfing conditions by creating waves that peel in a fast spilling or plunging manner and scattered the wave field creating multiple peaks. The berm was deposited in depths ranging from 1.5 m to 9 m below Mean Lower Low Water. The shore normal length of the berm, relative to the post deposition profile, is estimated at 450 m. Mesa states that the berm centroid was approximately 365 m from the beach and that the disposal area was ~90 m alongshore. An approximate value for the area is 0.04 km^2.

Midway, Gisborne, NZ

The focussing at Midway Beach in Poverty Bay, Aotearoa New Zealand, was studied by Beamsley and Black (2003). One of the most notable surf breaks in Poverty Bay is “The Pipe” (aka “Gizzy Pipe”). Beamsley and Black (2003) noted that the nearshore bathymetric contours at the Pipe are essentially shore-normal and not conducive to high quality surfing, similar to Aramoana (Kilpatrick, 2005; Scarfe *et al.*, 2009). Numerical modeling by Beamsley and Black (2003) showed a set of offshore reefs in Poverty Bay, known as the “Foul Grounds”, which includes Tokomaru Rock, Hawea Rock and Temoana Rock, precondition incident waves to produce more favourable surfing conditions through bifurcation of wave crests and doubling the breaking wave height at Midway Beach compared to the rest of Poverty Bay. The orientation of the system is shore normal and the offshore gradient of Temoana Rock is ~1:160. The distances from the shoreline to the toe and offshore foot of the feature is 1.1 and 3.2 km, respectively. The width of the feature varies along its length, at Temoana Rock the width is estimate as 300 m, the system broadens shoreward to approximately 500 m. The reef system shoals to 6 m (least known depth) below CD and is generally 7-11 m higher than the surrounding bathymetry. The approximate area is 0.8 km^2 with an estimated volume of ~7.5 Mm^3.

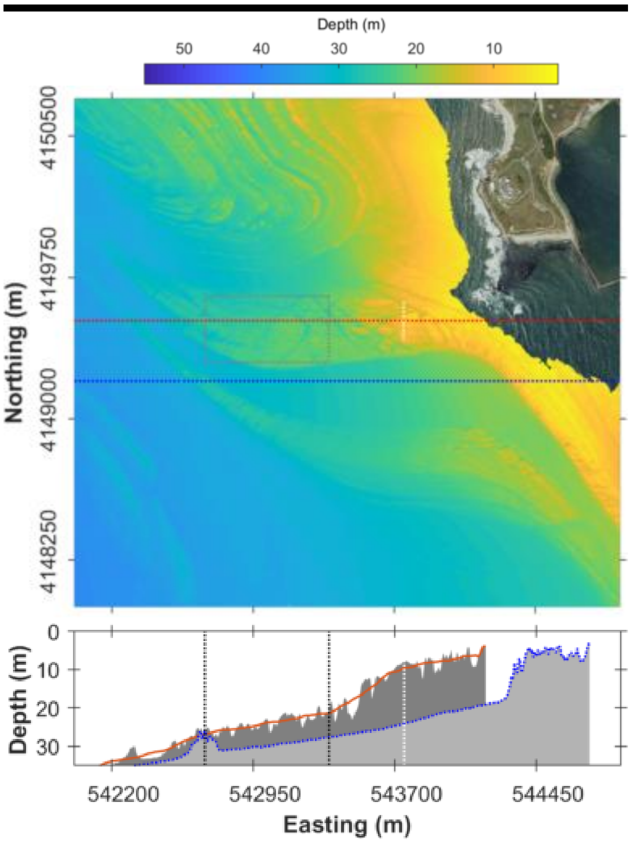


Figure 3. Top: multibeam bathymetry offshore of Pillar Point, Halfmoon Bay, US (Cochrane, *et al.*, 2014). With cross shore transect lines along (red) and adjacent (blue) to the preconditioning feature for Mavericks. The white line approximates the surfing area; black dotted lines demark the area considered for preconditioning. Bottom: depth profiles along the cross shore transects.

North Narrabeen and The Peak, NSW, Australia

Pitt (2009) identified 26 beaches in Australia that are controlled by offshore features or ‘Bomboras’, including North Narrabeen and ‘The Peak’ in New South Wales. Pitt (2009) provides bathymetric interpretations of these preconditioning features: the inshore toe of the reef at Narrabeen is 200 m from the shore and 7 m deep. The reef is a domed diamond shape, 400 m wide at the hip, tapering to around 50 m inshore. The offshore length is 750 m with the foot of the reef in water deeper than 17 m (CD). The reef shoals to 4 m above the ambient bathymetry. The outer slopes of the reef have gradients of 1:20. Given the approximate dimension the feature has a rough footprint and volume of 0.17 km^2 and 0.675 Mm^3, respectively. The Peak is 250 m from the shoreline and reportedly extends more than 750 m offshore. The reef is 500 m wide at 400 m offshore where the adjacent depth is 9 m. The reef narrows shoreward to 100 m wide where the adjacent depth is 3 m. The reef is to 2m above the ambient seabed offshore. The estimated footprint is 0.23 km^2, and volume 0.5 Mm^3.

Ocean Beach, California, USA

The surf break at Ocean Beach, California, US, is known for A-frames and for remaining surfable during larger swells whilst other nearby beach breaks are not. Battalio (1996) notes that refraction over the ebb tidal delta at the entrance to San Francisco Bay is the primary feature offshore which causes focusing of incident waves at Ocean Beach for most directions and especially for longer wave periods, but also for shorter period waves. From the ambient, adjacent bathymetry, the 20 m isobath (CD), some 2.3 km offshore, extends ~12 km (Cochrane, *et al.*, 2014). The inshore width, using Tennessee Point to the north as the demarcation is ~16 km. The offshore foot is rounded, and transitions to the ambient bathymetry very gentle, however the area is estimated at ~100 km^2. The delta shoals to 10 m CD, south of the San Francisco Bay shipping lane, particularly in an isolated area associated with a dredge spoil disposal sites, and ~7 m CD to the north on the Four Fathom Bank or Potato Patch Shoal. Basic estimates of volume indicate that the feature is slightly less than 960 Mm^3.

Rarotoka Island, Southland, NZ

Also known as Centre Island, off the Southland coast is one of Aotearoa New Zealand's premier big wave surf breaks. Mead *et al.* (2003) showed that a submerged ridge results in wave focussing into a singular peak, and not multiple surfing peaks. From the surfing area at Rarotoka Island, the offshore ridge is ~775 m, and the ridge runs ~2 km offshore west by south west. The ridge is 650 m wide at the offshore end widening to 900 m inshore. The offshore end is approximately 14 m deep (CD), 16 m above the ambient bathymetry (Mead *et al*, 2003). The feature shoals to 10 m at the inshore plateau, 5 m above the ambient bathymetry. Approximate values for area and volume are 1.6 km^2 and 16 Mm^3, respectively.

Summary of Study Site Data

Figure 4 presents the estimated volumes of the identified sites which range from 0.05 Mm^3 (the experimental, temporary Cronulla 'sand slug') to almost 960 Mm^3 (Ocean Beach). The mean volume of all sites is ~90 Mm^3, however, this is not particularly representative of the range of preconditioning features, with a standard deviation of ~290 Mm^3. The other extreme is the minimalist volume site of Cronulla. Excluding Cronulla and Ocean Beach the mean volume is 5.6 Mm^3 (σ 5.3 Mm^3).

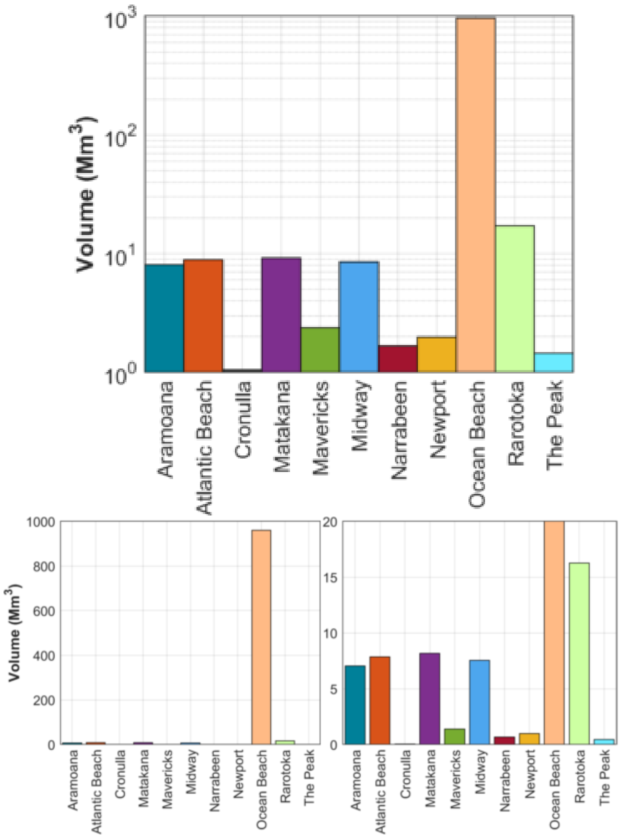


Figure 4. Volume estimates of features on a logarithmic scale (top), and standard volumes on the y axis at full extent (bottom left) and a reduced y axis extent (bottom right).

Figure 5 presents heuristic, scale representations of the estimated cross-sectional profiles and footprints. Ocean Beach, as with the volume estimates, dominates the axes area. Excluding Ocean Beach, all other foci are within 4 km of the surfing area. Excluding Atlantic Beach, Ocean Beach, and Matakana island, the longshore widths are all less than 800 m; excluding Aramoana as well leaves only foci with a primary axis that is shore normal, noting the ebb tidal deltas have relatively large inshore widths. Regarding basic shape, many of the sites have a trapezoidal type footprint, with the bulk being wider inshore than offshore.

There is a cluster of sites that are both close to shore and relatively smaller in footprint; this includes Cronulla, Newport Beach, North Narrabeen and The Peak. In this cluster the minimum distance from the shoreline to the inshore toe is 200 m (Cronulla and North Narrabeen), and the maximum is 365 m (Newport Beach). The minimum distance from the shoreline to the offshore foot is 600 m (Cronulla), and the maximum is 1000 m (The Peak). Inshore widths range from 50 m to 100 m, offshore widths range from 10 m to 500 m. The Peak and Narrabeen are both wider offshore than inshore.

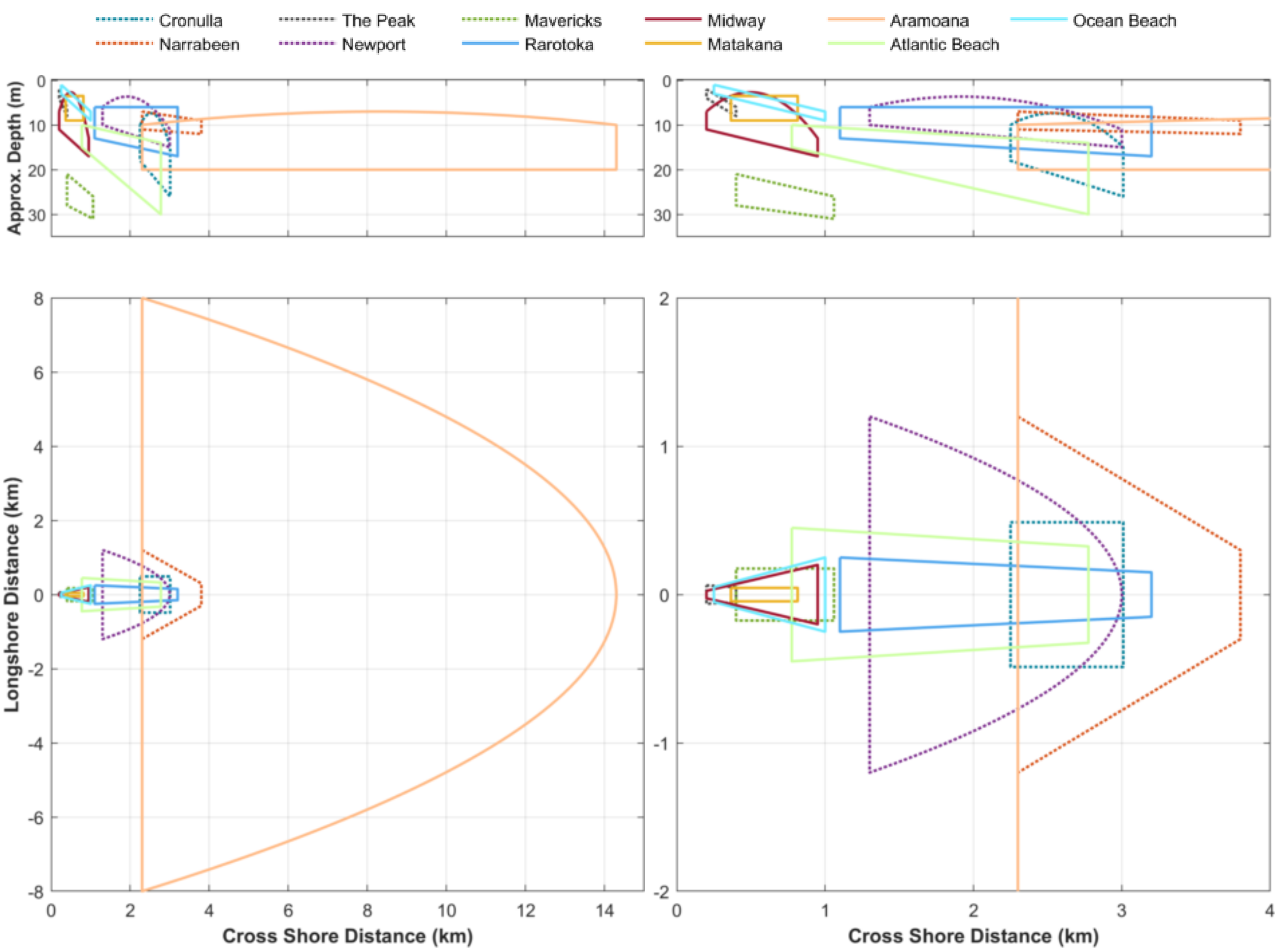


Figure 5. Heuristic profile (top) and footprint (bottom) estimates of features at full (left) and zoomed (right) view.

Numerical Modeling

The following section presents the results from the iterative numerical modeling tests and is broken into sections that consider each parameter that was changed. In excess of 55 scenarios were simulated, with 34 being used in this research. The most pertinent iterations from each case are provided in Figure 6 through Figure 11.

Pilot Configuration

Figure 6 shows that the pilot configuration exhibits bilateral focussing, with localised areas of increased wave height, or "peaks", associated with the two offshore corners of the rectangular feature. Inshore of this, the wave angle results in the formation of a singular peak in the lee of the feature; inshore of which, wave crests exhibit convex refraction. Adjacent to the singular peak (central to the domain) are regions of reduced wave height and phase shifts, in the order of 180 degrees, between segments of the same wave crests; also known as "crest snapping" or bifurcation. The surf zone is wide in the lee of the feature compared to the adjacent areas, and also in the case of the featureless planar beach.

Offshore Distance

Figure 7 shows that as the distance from shore to the feature increases, the degree of bilateral focussing reduces, wave crests become comparatively straighter (alongshore) and the surf zone becomes more comparable to the planar beach case. Moving the feature closer to shore extends the surf zone, and the 770 m case has the most apparent influence. This scenario reduces the amount of time for reorganisation, or for diffraction to 'repair' the wave crests before they reach the shore. The phase shifts between segments of the same wave crests are characterised by relatively reduced wave heights, and less definition in wave crests. It should be noted that feature depth increases with increasing distance from shore, as the feature was superimposed on a linearly declining seabed.

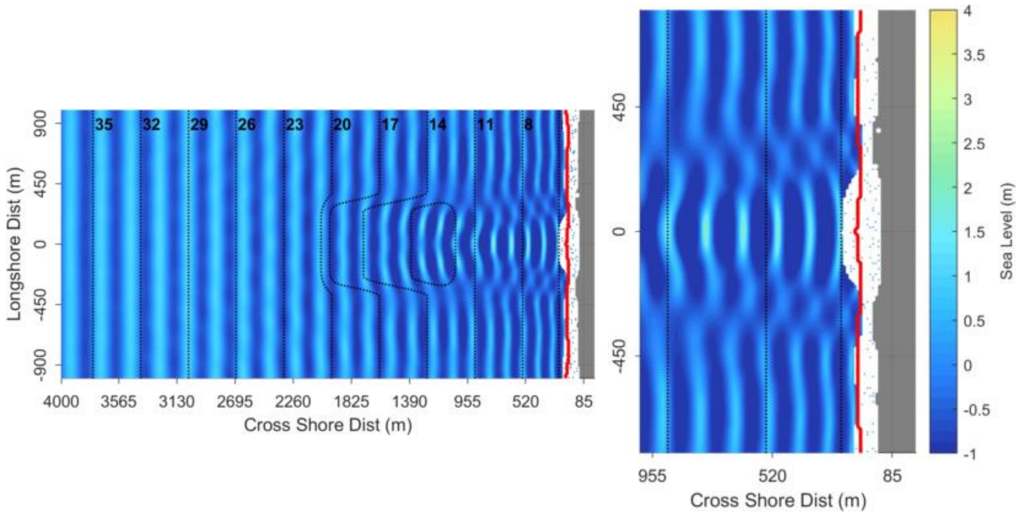


Figure 6. Model output of sea level from pilot configuration with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line); for full (left) and zoomed (right) view.

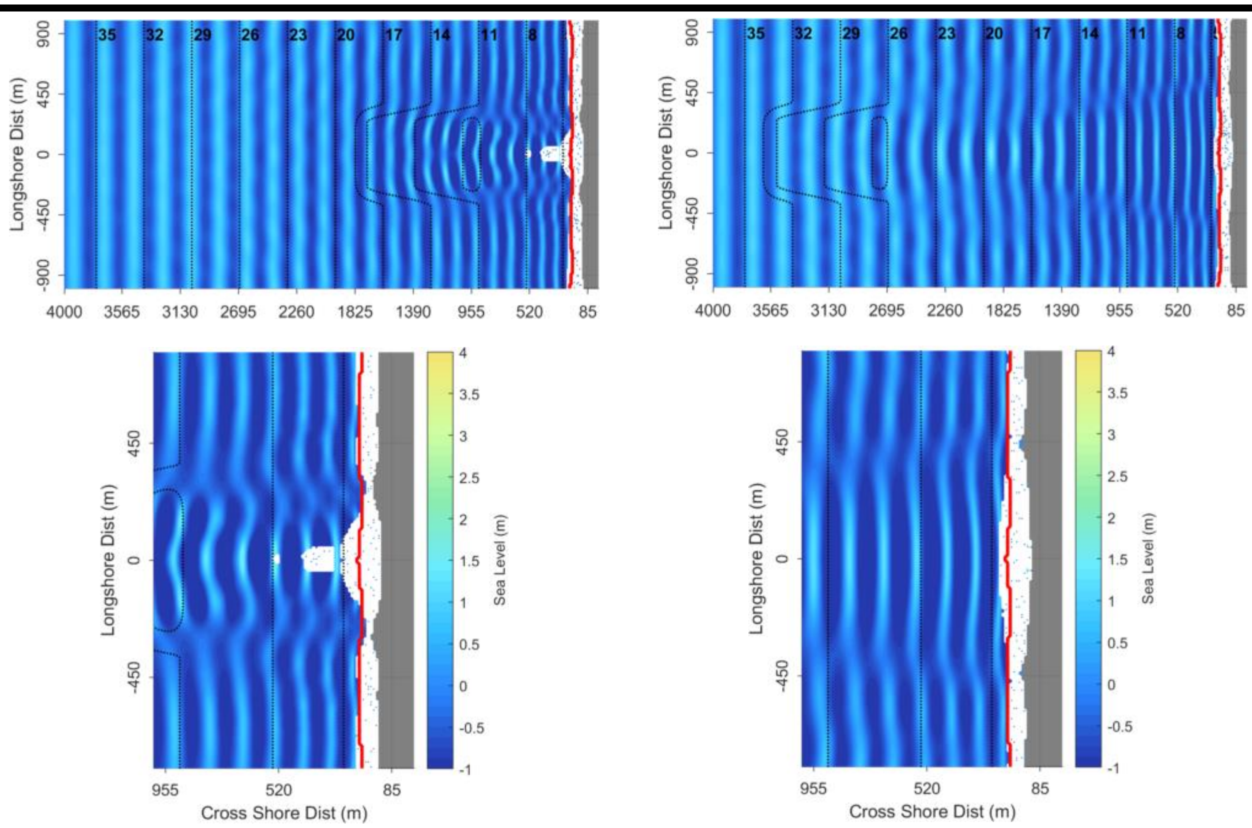


Figure 7. Model output of sea level with the toe distance set to 770 (left) and 2570 (right) m from the shore, with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line) ; for full (top) and zoomed (bottom) view.

Feature Height

A reduction in height of 2 m (original height 4 m) causes almost no discernible bifurcation of wave crests, yet notable wave height gradients (Figure 8) and bilateral focussing persists. Convex refraction is reduced, and the surf zone is still extended offshore in the lee of the feature.

Wave crests are still modified when the feature is reduced in height by 3 m, leaving 1 m of feature above the seabed. However, the seaward extension of the surf zone is minor, with the edge of the surf zone 15 m seaward of the pilot offshore limit. As feature height and surf zone width decrease, apparent changes, relative to the pilot feature surf zone, are more widespread in the longshore.

Feature Width

Bilateral focussing ceases to occur when the feature width is 320 m (Figure 9), some 200 m less than the pilot configuration (520 m width); instead a singular peak forms over the feature. Wave height in the peak produced in narrowest width case, 120 m, are smaller than those produced in the 320 m case. As the width increases the bilateral focussing becomes more apparent and in the widest case, 1120 m, results in separate peaks at the shore. Complete crest snapping does not occur in cases narrower than the pilot configuration, and in cases greater in width, the phase shift seems to decrease, or the severity of crest snapping reduces with increasing width.

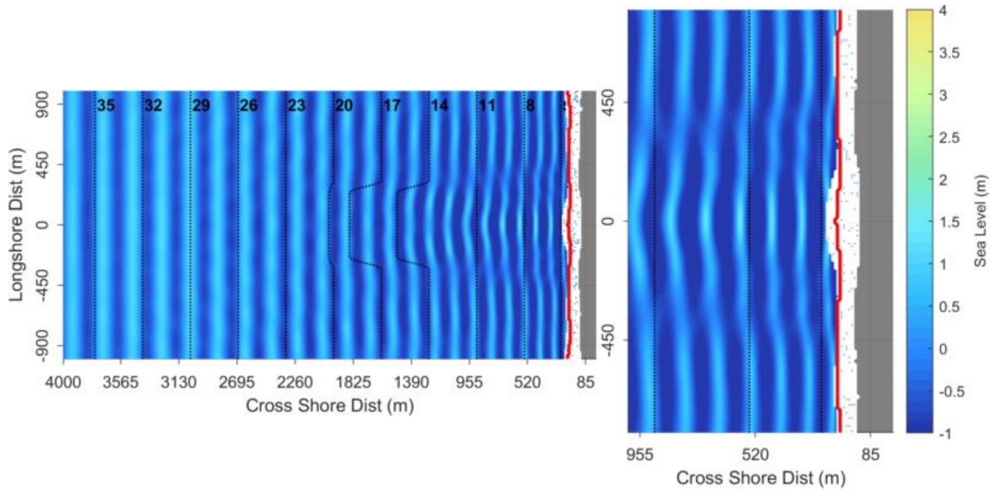


Figure 8. Model output of sea level for pilot configuration minus 2 m height, with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line); for full (left) and zoomed (right) view.

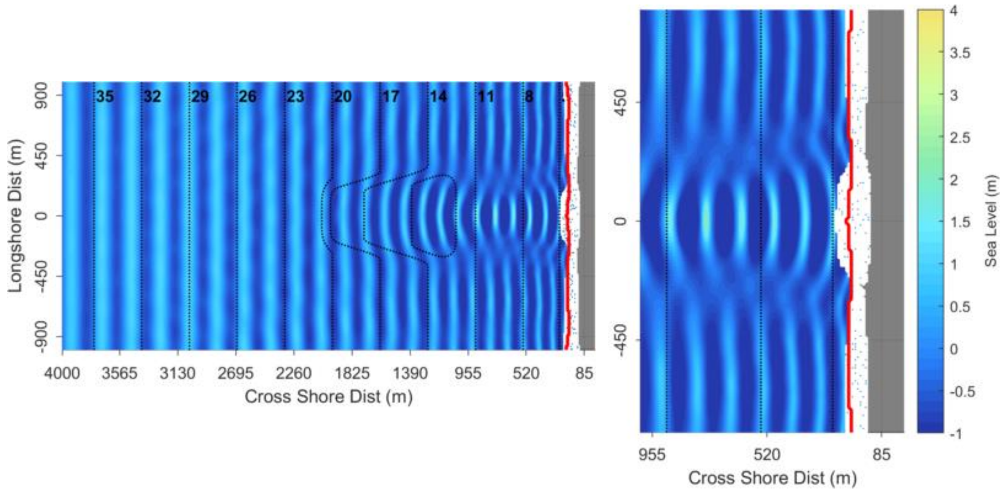


Figure 9. Model output of sea level with feature width set to 320 m at both foot and toe ends, with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line); for full (left) and zoomed (right) view.

Offshore Width

The narrowest and widest of the offshore width cases are presented in Figure 10 and Figure 11. Decreasing offshore width relative to inshore width results in more singular focussing. Increasing the offshore width tends to more non-linear wave patterns in the lee of the feature, which occurs with a greater degree of refraction. Wave crests from opposite longshore sides of the feature orientate perpendicular to one another – the result is more wave-wave interactions (interference) and widespread crest snapping. The widest case, 1120 m offshore / 520 m inshore, results in multiple extensions offshore of the surf zone.

Scale

Figure 12 presents the extreme footprint scale cases. As the footprint of the feature is reduced, waves in the lee exhibit more convex refraction and singular focussing becomes more pronounced. When the feature increases in footprint (twice width and length of the mean), bifurcation ceases, yet wave height gradients persist with wider spread shadow zones. The mean configuration in these cases results in the greatest extension offshore of the surf zone, however smaller scale features maintain a notable and similar change in the surf zone width.

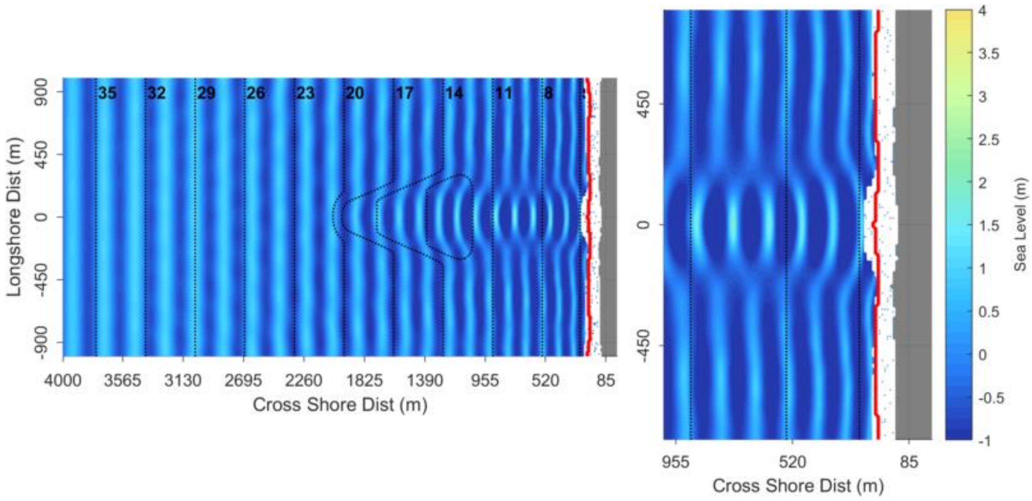


Figure 10. Model output of sea level for offshore width set to 120, with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line); for full (left) and zoomed (right) view.

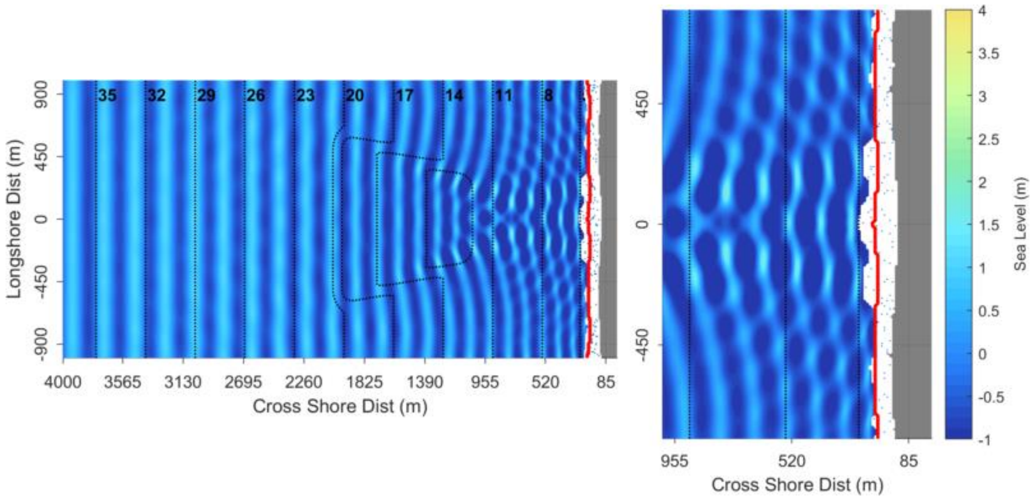


Figure 11. Model output of sea level with features offshore width set to 1120, with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line); for full (left) and zoomed (right) view.

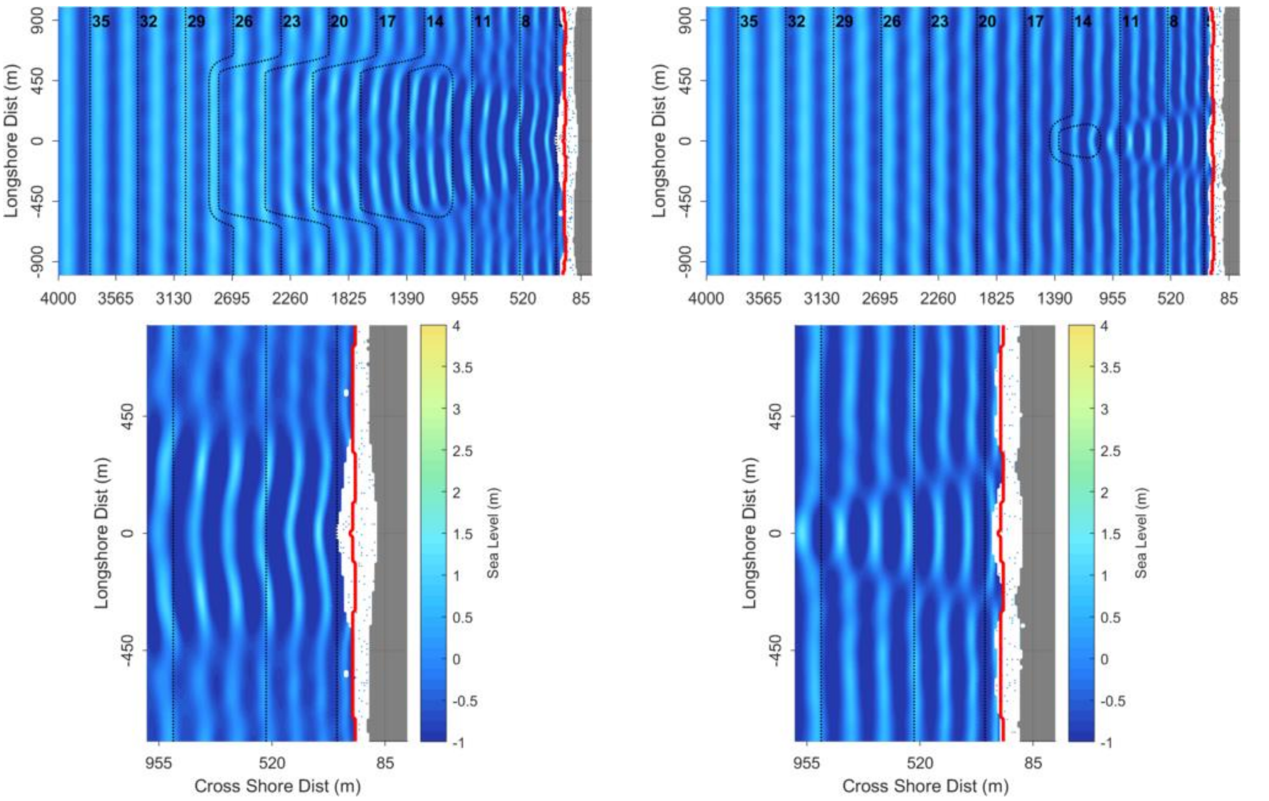


Figure 12. Model output of sea level with footprint multiplied by 2 (left) and reduced by a factor of 3.5 (right), with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line) ; for full (top) and zoomed (bottom) view.

Apron

Figure 13 shows that decreasing the gradient between the feature crest and the ambient seabed reduces the occurrence of bifurcation, results in more concave wave crests in the lee of the feature, and, generally, more ubiquitous along-crest wave heights. As apron gradient decreases from 0° through to 60° the offshore extent of the surf zone increases, with a narrow, localised, point of breaking in the 60° case. Lower gradients see the surf zone reduce in width.

Volume Comparison

The average volume for all features used in simulations is 2.41 Mm^3. The maximum volume feature, 8.2 Mm^3, was produced from the 0.5 scale factor iteration. This volume is comparable to Aramoana (~7 Mm^3), Atlantic Beach (~7.9 Mm^3) and Midway (~7.6 Mm^3). The next two highest volumes from simulated features are from apron angle adjustments, 5.9 Mm^3 and 4.9 Mm^3 for 150° and 120° aprons. The minimum volume simulated is 0.34Mm^3. This is around seven times more volume than that used at Cronulla, which is noted as being effective during its duration.

DISCUSSION

Little is known about the natural offshore preconditioning of waves that result in wave breaking patterns that are conducive to surfing. Consistent with Mead and Black (2001b) and Mead *et al.* (2003), this research shows offshore preconditioning features occur on a very wide range of scales. It also shows that relatively small features can have a distinct effect on wave breaking patterns, and that certain characteristics influence the type of preconditioning.

Pitt (2009) notes that beach breaks associated with offshore features are popular because they provide relative certainty and localisation of wave peaks and energy. Offshore features can act in two ways, which are not mutually exclusive. They can provide a control and focus point, which often results in a singular, defined peak. They can also introduce seemingly chaotic conditions by promoting bifurcation of wave crests and/or wave-wave interactions. In both cases the added dynamisms to the wave breaking process promotes "surfable" conditions that are ultimately a function of depth limited breaking and dependent on longshore wave height gradients.

A common theme of waves associated with offshore focus features is "peakiness" or an A-frame character. Mavericks and Rarotoka are distinctly different in terms of surfing functionality when compared to the other sites considered here, as they are both big wave surfing locations. These features create be formed by a localised ray of focussed wave height, rather than disrupting wave crests over a large stretch of coast and creating multiple peaks and therefore surfing opportunities, which is what occurs at Ocean Beach for example.

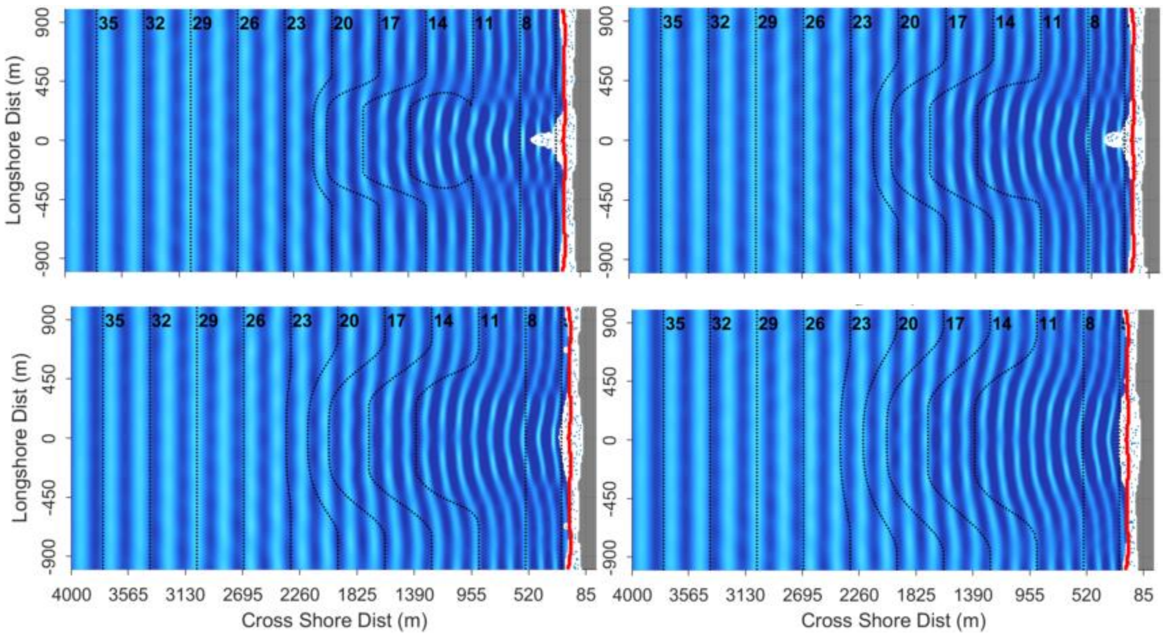


Figure 13. Modelled sea level with apron angles of 60° (top right), 90° (top left), 120° (bottom right), 150° (bottom left), with depth isobath (black dotted lines), surf zone (textured white) and offshore limit of the planar beach surf zone (red line).

While the term preconditioning is used to describe the process of modifying wave crests prior to breaking, where wave height gradients are the result of bifurcation and wave-wave interactions, and especially where incident wave spectra tends to monochromatic and wave crests are well groomed by dispersion, and to keep in line with established terminology, this process could be referred to as *disruptive preconditioning*. This is opposed to a singular or more defined surfing peak that results from *focus preconditioning*, which is more akin to the focus functional reef component of Mead and Black (2001b); where the focus is often proximal to the surf break area and/or seamless transitions in bathymetry are observed and can also be the feature that initiates breaking.

The approach taken here considered and quantified a limited number of natural preconditioning features and used these data to construct a numerical model to simulate wave propagation and breaking patterns, with incremental changes to a pilot model bathymetry.

The role of an offshore preconditioning feature can change from disruptive preconditioner to focussing preconditioner and even a focus breaking component (*e.g.*, a take-off zone) with changes to wave height, period, direction and water level. These transitions are a function of incident wave conditions relative to the size of the seabed feature and its ambient bathymetry. For a fixed wave condition, as a feature increases in footprint (scale) the effect will transition from focus preconditioning to disruptive. It is hypothesized then that, for a fixed feature as wave height increases the response will transition from disruptive to focussing to inconsequential as the feature becomes irrelevant to the scale of the wave. However, this will also be influenced by the incident wave characteristics such as wave period. Future research will focus on addressing these relationships, and whether empirical models for practical application can be established.

The case of Aramoana is very complex, with multiple bathymetric features interacting with the incident waves prior to breaking. Included in future work will be testing of the method for isolating offshore preconditioners by decomposing the surf break such as the work of Mead and Black (2001b) and Scarfe *et al.* (2003).

It is important to note that there is no morphological response included in numerical model simulations presented here. It is very likely as wave propagation and breaking patterns are being altered then the nearshore will develop features such as varied bars and channels which will have a profound feedback on further propagation and breaking.

West *et al.* (2003) concluded that a feature with a height:width:length ratio smaller than 1.5:10:40 m would have no influence on breaking patterns. Scenarios of features this small have not been included in this modeling framework as the features created here were largely driven by real life world examples. Future work will also explore the lower limits of size, position and volume for effective preconditioning. West *et al.* (2003) also made observations concerning distance from shore, and while this parameter was studied here, a fundamental flaw was depth increasing with distance from shore. Future work will include a planar beach scenario with a range of slopes, to determine "repairing" or restoring factors or distances.

This work shows a relationship between feature width and the creation of multiple or singular peaks through refraction. Further investigations will attempt to define a cut-off, between bilateral and singular focussing, and if a relationship can be established between the level of bifurcation and feature characteristics, noting that processes being studied are chaotic. It is likely that these processes, and resultant peaks and breaking patterns are related to the relationship between wavelength and the size of structure.

This research has taken a very simple approach for estimating preconditioning feature characteristics and it is understood that the orthogonal of waves will rarely follow such linear approximations of the features. The pilot feature constructed is also very linear, with little to no curvature, especially on the feature crest. Therefore, the effects of curvature in the feature crest, aprons and footprint should also be further considered.

In summary, the investigations presented here have provided valuable insight into the effects of scale and morphology of offshore focussing features such as the delineation between focusing of single wave peaks or disruptive focussing forming multiple wave peaks at the beach. Even so, there are many aspects of preconditioning component functionality that still need to be addressed, including orientation and relationships between focus design, and incident wave climate and shoreline response. Further investigations will consider the methods for describing and delineating focussing features in detail. In parallel, methods for quantifying the effects of a focus could be standardised in order to establish empirical relationships.

CONCLUSIONS

A database of seabed features that precondition waves prior to breaking, and directly result in surfable conditions, has been compiled. The database has been used as both a starting point for modelled feature design and as the stimulus for model scenarios. This investigation has shown what type of basic forms are conducive to surfable conditions and could inform the design stages of manmade offshore preconditioning structures. This work adds to our understanding of the functionality of preconditioning components of surf breaks, which improves our capacity to sustainably manage surfing resources but also provides preliminary guidance regarding the disposal of material in the marine environment with a view to integrating surfing amenity in to management plans of infrastructure such as ports and marinas.

ACKNOWLEDGEMENTS

This work was funded by UNITEC Institute of Technology and was integrated into the Aotearoa New Zealand Ministry for Business, Innovation and Employment contract UOWX1502.

LITERATURE CITED

Atkin, E.A.; Bryan, K.; Hume, T.M.; Mead, S. T., and Waiti, J., 2019. *Management Guidelines for Surfing Resources*. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research, 114p.

Atkin, E.A.; Mead, S.T.; Bryan, K.; Hume, T., and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. *Proceedings of the 23th Australasian Coasts and Ports Conference*, Cairns, Australia, 21-23 June 2017.

Battalio, B., 1994. Estimating braking wave height at Ocean Beach, San Francisco. *Shore and Beach*, 62(4).

Beamsley, B. J. and Black, K.P., 2003. The Effect of Offshore Reefs on Inshore Surfing Conditions. *Proceedings of the 3rd International Surfing Reef Conference*. Raglan, New Zealand.

Cochrane, G.R.; Dartnell, P.; Greene, H.G.; Johnson, S.Y.; Golden, N.E.; Hartwell, S.R.; Dieter, B.E.; Manson, M.W.; Sliter, R.W.; Ross, S.L.; Watt, J.T.; Endris, C.A.; Kvitek, R.G.; Phillips, E.L.; Erdey, M.D.; Chin, J.L., and Bretz, C.K., 2014. California State Waters Map Series—Offshore of Half Moon Bay, California: *U.S. Geological Survey Open-File Report 2014–1214*.

Department of Conservation, 2010. *New Zealand Coastal Policy Statement 2010.* Wellington: Department of Conservation.

Kilpatrick, D., 2005. Determining Surfing Break Components at Aramoana Beach, Dunedin. Otago, New Zealand: University of Otago, Post Graduate Diploma Research Thesis.

LINZ, 2015. Tauranga Harbour - Katikati Entrance to Mount Maunganui: NZ5411. Wellington: Land Information New Zealand.

LINZ, 2018. Otago Harbour North: NZ6612. Wellington: Land Information New Zealand.

Hutt, J.A.; Black, K.P., and Mead, S.T., 2001. Classification of Surf Breaks in relation to Surfing Skill. *In:* Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, *Journal of Coastal Research*, Special Issue No. 29, pp. 66-81.

Mead, S.T., and Atkin, E.A., 2019. Managing Issues at Aotearoa New Zealand's Surf Breaks. In: Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 13–22.

Mead, S.T. and Black, K.P., 2001a. Field Studies Leading to the Bathymetric Classification of World-Class Surfing Breaks. *In:* Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, *Journal of Coastal Research*, Special Issue No. 29, pp. 8-20.

Mead, S.T. and Black, K.P., 2001b. Functional component Combinations Controlling Surfing Wave Quality at World Class Surfbreaks. *In:* Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, *Journal of Coastal Research*, Special Issue No. 29, pp. 21-32.

Mead, S.T. and Black, K.P., 2001c. Predicting the Breaking Intensity of Surfing waves. *In:* Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, *Journal of Coastal Research*, Special Issue No. 29, pp. 51-65.

Mead, S. T.; Black, K.P.; Frazerhurst, J., and Scarfe, B., 2003. The Effects of Wave Focusing on Surfing Reef Site Selection, Surfing Wave Quality and ASR Design at Scales of Inner Continental Shelf to Sub-Tidal Reef. *3rd International Artificial Surfing Reef Symposium*, Raglan, New Zealand 23-25 June 2003. ISBN 0-473-09801-6 2003.

Mesa, C., 1996. Nearshore Berm Performance. *Proceedings of the 25th International Conference on Coastal Engineering*.

Pitt, A., 2009. Surfing at Bombora Controlled Beaches. *The 5th Western Australia Coastal Conference*, Freemantle, WA.

Pitt, A., 2010. Proposal for an Ephemeral Bombora at Cronulla. *Report Prepared for the Bate Bay Sand Place Committee, Cronulla, NSW*.

Pitt, A. 2012. *Wave Focusing Sand Slug…an update*. Cronulla, Australia.

Scarfe, B.E.; Elwany, M.H.S.; Black, K.P., and Mead, S.T., 2003. Surfing Conditions around Jetties. *Scripps Institution of Oceanography*. Technical Report, 92p.

Scarfe, B.E.; Healy, T.R.; Rennie, H., and Mead, S.T., 2009. Sustainable Management of Surfing Breaks—Case Studies and Recommendations. *Journal of Coastal Research*, 25(3), 684–703.

Walker, J. R.; Palmer, R. Q., and Kukea, J. K., 1972. Recreational Surfing on Hawaiian Reefs. *Proceedings of the 13th Coastal Engineering Conference.*

West, A., 2002. Wave Focusing Surfing Reefs: A New Concept. Delft, The Netherlands: Delft University of Technology, Masters Thesis.

West, A., Cowell, P., Battjes, J. A., Stive, M. J. F., Doorn, N. and Roelvink, J. A., 2003. Wave Focusing Surfing Reefs: A New Concept. *Proceedings of the 3rd International Surfing Reef Conference*. Raglan, New Zealand

8 Deep Learning Object Detection Application to Surfing Wave Quality

Publication details:

Atkin, E.A., Davies-Campbell, J. and McIntosh, R., 2022. Deep Learning Object Detection Application to Surfing Wave Quality. Coastal Engineering, 37.

The publisher has been granted permission to reproduce this article in the published format. Pagination of the reproduced article is carried over from publication and not synchronised with the main body of this thesis. Page references to any errata are relevant to the publication.

This paper leverages one of the camera systems established as part of the overarching research project. Information regarding camera equipment and more detailed methodologies for installation were compiled in a technical report[5]. This work established a method for automating the identification and tracking through space and time of the breaking part of a wave and the orientation of the wave crest through machine learning. The outcome of this work was to enable the first automation of a meaningful surfing wave quality monitoring system. The importance of this relates to the establishment of environmental baselines and having an understanding of coastal resources for effective, sustainable management.

Chapter Errata

Cor – correction of language

Page/Line	Original text	(type of correction) Corrected text
3	"Ground Control Points (GCPs) for were collected with high accuracy GPS …"	(Cor) "Ground Control Points (GCPs) were collected with high accuracy GPS …"

Figure 2 states there is an *"orange (top row) GCP flag left of centre".* The published quality of the image does not resolve the GCP flag. The location of the flag is highlighted with a red circle in the image below:

[5] Remote Monitoring Camera Systems

This paper refers to unusable training iterations without providing clarity as to why they were not included in the final analysis. This work was in part an exploration in to the tuneability of the Convolutional Neural Network. This involved the alteration of the model's settings (hyperparameters). Some alterations, especially those testing the limits of prescribed model setting values, and despite the model running its course in time, resulted in invalid or incomparable outputs.

DEEP LEARNING OBJECT DETECTION APPLICATION TO SURFING WAVE QUALITY

Edward A Atkin[1,2,3] , Jai Davies-Campbell[1] and Rhys McIntosh[1]

Quantitative monitoring is imperative to the sustainable management of coastal resources. Surfing resources have been both created and degenerated or destroyed by activities in the coastal zone. Effective surfing wave quality monitoring requires identification and tracking of the breaking part of the wave and the unbroken wave crest. Remote Camera Systems (RCS) have proven their utility in being able to monitor the coastal zone and provide almost continuous, high frequency data collection. RCSs lend themselves very well to the monitoring of surf breaks which are highly dynamic. The images captured from an RCS monitoring a surf break on the west coast of Aotearoa New Zealand are used to train a Convolutional Neural Network (CNN) to detect the break points (BP), associated crest orientation and relative Still Water Level (SWL) of each instance of breaking waves in each image. Model settings and image annotations were modified over a suite of training cases to improve model efficacy, which was evaluated each epoch of training with mean Average-Precision (mAP; max 1). A mAP of 0.794 was achieved for the BP and Crest Point (CP) CNN, and 8.634 for the SWL. The model was used to detect ~1.6 M objects across ~1 million images, with a mean confidence value of all BP-CP detections of 0.63 and more than 70% of detections being greater than 0.5. This model enables the first automation of meaningful surfing wave quality monitoring.

Keywords: surfing resource, surf break, sustainable management, convolutional neural network, environmental monitoring, remote camera system

INTRODUCTION

Of the metrics for quantitatively evaluating surfing wave quality, which are best summarised in Mead (2000), peel angle (α) (Hutt et al. 2001; Walker et al. 1972; Walker 1974) could be considered the most imperative. Walker et al. (1972) describe α as the angle between the unbroken wave crest and the velocity of the surfer, and it directly relates to the speed at which the breaking part of the wave translates laterally. Open face surfing can be undertaken in a range of breaker types and shapes, from spilling right through to collapsing waves (Battjes 1974; Galvin 1968; Iribarren and Nogales 1949; Mead and Black 2001c; Wiegel 1964). However, if the wave does not peel at a suitable rate (the peel angle is too large or small), at either end of the wave breaking spectrum, the surfer cannot translate laterally along the wave face. Wave shape is a surfing wave quality characteristic that is extremely difficult to monitor. In contrast, peel angle is a surfing quality characteristic that can be readily monitored (Atkin 2010; 2021; Davies-Campbell 2018; McIntosh et al. 2018).

Commonly, the trail of broken white water and the crest of the unbroken part of the wave is used to measure peel angle (e.g., Atkin 2010; Davies-Campbell 2018; Hutt et al. 2001; Mead 2000). Most evaluations of α have made use of aerial photographs (Hutt et al. 2001; Mead 2000; Mead and Black 2001a,b,c; Walker 1974), and more recently repeat satellite imagery (e.g., Atkin et al. 2021). These approaches are often limited both spatially and temporally. Following recommendations in Scarfe (1999), Atkin (2010) used oblique photogrammetry to monitor a Multi-Purpose Reef (MPR) that was constructed at Boscombe in the UK. The approach captured wave breaking conditions during a range of wind, wave, and tidal conditions. The resulting dataset compared well to the MPR's design phase, which showed how the MPR modified α values compared to a proximal control site. The approach by Atkin (2010) was manual collection, georectification, annotation and measurement of peel angles, and, ultimately, was a labour-intensive study.

The use of Remote Camera Systems (RCSs) in the monitoring of coastlines (Holman and Stanley 2007) and their ability to collect repeatable, high frequency data, is ideally suited for studying the dynamic process of wave breaking. The capability to accurately georectify images using Ground Control Points (GCPs) that describe pixel locations in real world coordinates allows for quantitative measurements of geophysical phenomena.

In 2017, a research program focused on addressing the lack of clear quantitative measures and guidelines describing the characteristics and functionality of surf breaks in Aotearoa New Zealand established five RCSs (Atkin et al. 2017; 2019a,b). One of the RCSs was established with a Field of View (FoV) of Waikeri (Manu Bay), on the west coast of Aotearoa New Zealand's North Island (Figure 1). Waikeri is a left-hand (where waves break from left to right when viewed from the land)

[1] eCoast Marine Consulting and Research, 18 Calvert Road, Raglan, 3297, Aotearoa New Zealand.
Email: e.atkin@ecoast.co.nz
[2] University of Waikato, Hillcrest, Hamilton, Aotearoa New Zealand
[3] International Association for Surfing Research

point break (Mead 2000), a Surf Break of National Significance (Department of Conservation 2010) and considered world class.

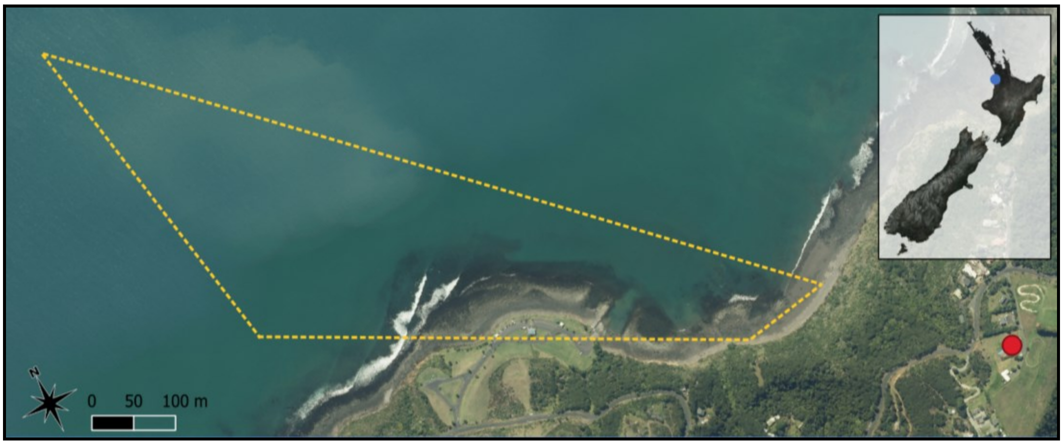


Figure 1. Inset: National location of Waikeri (blue circle). Main: Aerial photo (LINZ) of Waikeri showing camera location (red circle) and the RCS FoV real world footprint (amber dashed line).

During the research project data from the Waikeri RCS was used to develop an automated system to measure peel angle from geo-rectified images (McIntosh et al. 2018). The results were of similar accuracy to manual digitisation; however, the system was time and computationally intensive, and required some filtering of outliers to create the final dataset. Machine learning provides the opportunity to automate tasks and reduce the overhead of manual input. Stringari et al. (2019) used pixel intensity and true colours to develop a one dimensional, cross-shore, broken wave detection algorithm for RCSs in New South Wales, Australia. The work tracked the bore of white water generated during wave breaking as it moved shoreward on a predefined transect, roughly orthogonal to incident wave crests. Kim et al. (2020) used a Neural Network (NN) to track key points of broken and unbroken wave crests in the surf zone. NNs use numerous interconnected nodes, like the synapses of the brain, that process input data. NNs need to be trained to do this with comprehensive datasets and have been shown to be very effective at classifying data and, in particular, the detection of objects in images.

Stringari et al. (2021) also used a pixel intensity approach to isolate foam generated during breaking and distinguish it from passive foam and non-breaking areas. Subsequently, a NN was trained to distinguish between active and passive foam. While this capability was less discrete than the work of Stringari et al. (2019) and Kim et al. (2020), which are spatially limited, these approaches are not definitive enough to describe breaking characteristics for surfing wave quality. A more specific approach is that of Thompson et al. (2021), who used 1,300 labelled images to train a Convolutional Neural Network (CNN) to track the approximate breaking area of the wave, or leading edge of the breaking part of the wave, in oblique images. While the work of Thompson et al. (2021) provides quantitative data to describe surfing amenity, such as ride length, it fails to capture the fundamental components required for measuring α – the unbroken wave crest and point of instantaneous breaking. The work presented here describes how a CNN object detection model (Jocher et al. 2020) was trained to be used in the monitoring of α at Waikeri. The model was selected as it provides accurate object detection faster than other CNNs (e.g., Li et al. 2020), has real-time capability (Malta et al. 2021) and it is efficient (Nepal and Eslamiat 2022 and references therein) - which is important for RCSs with power and compute limitations if the detection model is deployed on site.

METHODOLGY

The following section outlines the steps in the application of a CNN to images of breaking waves collected by the Waikeri RCS and is broken down in to five subsections: Collection, Preparation, Annotation, Training, and Application.

Data Collection

The RCS at Waikeri was established in May 2017 and this work considers images up until June 2020. Ground Control Points (GCPs) for were collected with high accuracy GPS (post processed kinematic) in November 2017. The RCS uses an off-the-shelf security camera with a 9~40 mm, 5 megapixel telephoto lens collecting 1,200 images at 1 Hz every hour, each day during daylight hours. Image cubes refer to a stack of images collected overtime. With the exception of the midday collection, image cubes were processed on site to extract image products (e.g. Bruder and Brodie 2020 and references therein) and subsequently discarded. This work uses the midday image cubes (all 1200 images).

Data Preparation

A calibration of intrinsic characteristics of the camera monitoring Waikeri was undertaken using methodology from Bouguet (2015), the output of which is used in the georectification of camera images and image derived data. The software tools, developed by Bruder and Brodie (2020), and GCPs were used to calculate the position and orientation of the camera to develop a georectification matrix for the conversion of pixel related data into real world coordinates.

To account for any movement in the RCS, images were registered/aligned to permanent features (e.g., buildings; Rodriguez-Padilla *et al.* 2020) relative to a baseline image collected at the time the GCPs were established. The registration was undertaken in three steps: 1) a first pass Discrete Fourier Transform (DFT) method (e.g., Guizar-Sicairos *et al.* 2008) was applied to a cropped subset, greyscale image, focussed on buildings in the Field of View (FoV), and was used to reduce any larger-scale offsets; 2) individual subset DFTs of five notable features in subset images were highlighted using Canny edge detection. If the DFT shift values from a particular subset exceeded three pixels (in x or y), the shift values were omitted; and, 3) the subset DFT shift values were used to estimate a similarity transform, and the transform was used to warp the features to the baseline image (e.g., van der Walt *et al*. 2014).

To reduce image size and focus training, images were cropped at the horizon and in unnecessary land areas, and any remaining areas that were not of interest to training were masked (*e.g.*, car park, foreground building; Figure 2).

Figure 2. Original FoV image from 1300 hrs on the 30th November 2017 (top left), registered image showing slight right to left and up down shift in camera (top right), and grey scale version of the registered image that is cropped and masked (bottom). Note the orange (top row) GCP flag left of centre.

Annotation

Preliminary trials used a mask region-based CNN (He et al. 2017). Using a fixed size box, centred on the leading edge of the breaking part of the wave, as it translates laterally, multiple instances of the broken part of the wave were successfully detected by the neural network. Different sized and shaped boxes were tested, which indicated that model effectiveness was sensitive to the labelling strategy. The labelling of the training dataset in this way, and the resulting identified object (box), provided no means of isolating the crest of the wave, which is integral to the measurement of peel angle.

The data required to train the object detection model (Jocher et al. 2020) consists of an image-normalised x,y location with a width and height to depict a box for each instance of an object, in each image. The features targeted for annotation were the Break Point (BP) and unbroken crest of the wave. The boxes used in the model are orthogonal to the pixel orientation. Wave crest orientation can vary spatially, especially where refraction is taking place, which is common to point breaks (Mead 2000). Wave section length (Moores 2001) was used as a reference for delineating annotation boxes. To accurately annotate these features, an interface was developed to simultaneously view and annotate each image in oblique and geo-rectified views, the latter of which allowed for spatial limitations to be applied (Figure 3).

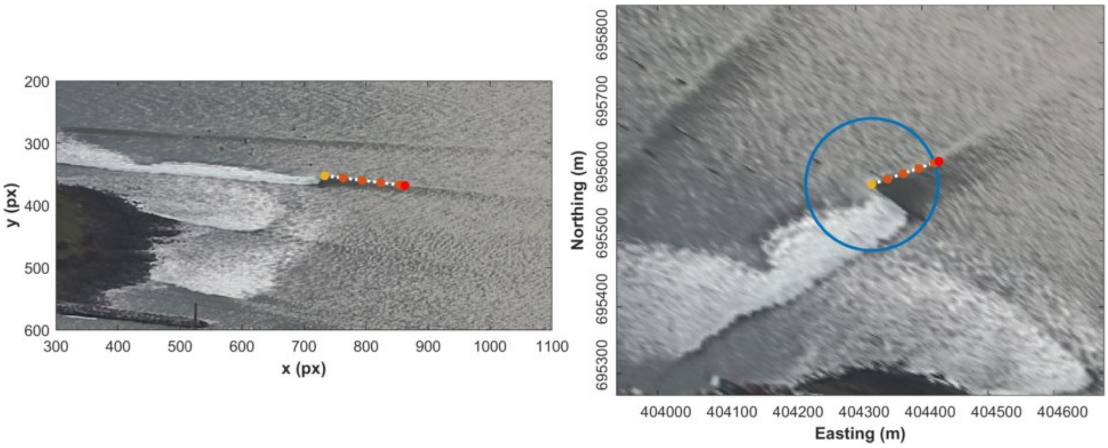


Figure 3. Annotation views of original image (left) and georectified (right), including BP (yellow), crest line (white dashed line) and end point (red), and 5 m CPs (orange).

In ~3,700 images, where each peeling wave was identified: the BP was annotated, and represented with a single x,y location; the BP was used to anchor a 20 m concentric line, within which the crest was considered linear; and, a polyline, anchored to the BP, was aligned to the unbroken crest of the wave and extended beyond the 20 m concentric mark. The output included the coordinates of the BP and the intersect between the polyline and the 20 m circle, the Crest Point (CP). Coordinates were interpolated at 5 m intervals between the BP and the CP to provide CPs at 5, 10, 15, and 20 m from the BP (Figure 3). During annotation, left-hand waves that were not breaking directly on to the shore were digitized. If an image contained no objects, no discernible peeling waves, or if BP were not easily resolved (e.g., during storm events, rain drops on the camera housing window, time of intense sun glare, low light levels etc.) the annotation data for that image was left empty.

Detected object boxes were labelled using the annotation data. Several Training Sets were developed during the study, the key characteristics of which are presented in Table 1. Training Sets 1 and 2 used boxes delimited by the BP and the last CP (*i.e.*, 20 m from the BP); Training Set 2, and all subsequent sets, used greyscale images, which reduced the amount of data that required transferring as well as memory/computational requirements.

From Training Set 3 onwards, the box extent was expanded, doubling in width and height, centred on the BP. This transition was made to include more pixel information in training objects, which was particularly important for far field objects where the difference in the y location of the BP and CP were small, resulting in a narrow object box.

In Training Sets 4 and 5 the second CP (10 m) were used. The third CP (15 m) was used in Training Sets 6, 7, and 8. Training Sets 4 and 6 incorporated an object class which denoted the location of the CP relative to the BP in the oblique image, either above or below, so that crest orientation could be determined in post processing. Of 3,769 annotated breakpoints for the Waikeri training dataset, 98.8% had an BP above the CP. Training Set 8 included only those objects where the CP was below the BP.

Table 1. Training dataset configurations. Colour refers to either Red, Blue, Green (RGB) or Greyscale (GS), Extent refers to the labelling of breaking waves where the Original extended from the Instantaneous Break Point (BP) to the Crest Point (CP), and Expanded quadrupled the area of the bounding box centred on the BP. Class considered the position of the BP relative to the CP within an image.

#	Colour	Extent	CP	CP Class
1	RGB	Original	Last	None
2	GS	Original	Last	None
3	GS	Expanded	Last	None
4	GS	Expanded	Second	Above/Below
5	GS	Expanded	Second	None
6	GS	Expanded	Third	Above/Below
7	GS	Expanded	Third	None
8	GS	Expanded	Third	Below

BP location, at the top of a wave, requires translating to a position at Still Water Level (SWL). Thompson et al., 2021 used a generic offset of 1/5 of the pixel distance between the shoreward edge of the white water bore and the breaking crest to account for the set down Infront of the wave and translate a pixel location to a SWL. Shand et al. (2012), who used a dual camera system to detected breaking waves height, used 1/3 of the position between the crest and trough. Using a constant offset may have been considered effective for waves that are breaking directly toward a cameras FoV However, the assumptions are not applicable to images collected at Waikeri. The broad range of wave breaking types and significant wave refraction occurring at the point break result in Break Points at Still Water Level (BPSWL) being close to the BP right through to being in line with the leading edge of the white water bore. It was observed that not every section of white water bore projects to the base of the wave during breaking, the difference being plunging and spilling waves, which is consistent with Shand et al. (2012).

To account for the BPSWL discrepancy, a second CNN was developed. Annotations for the BPSWL CNN in unrectified images were constrained by the left-right pixel location of previously annotated BPs. The up-down location was estimated using the apparent location of the white water bore and wave breaking shape. Bounding box geometry was a function of the vertical offset in pixels between the annotated BP and BPSWL – the height and width being 2 and 4 times the offset, respectively, the bounding boxes centred on the BP.

Training

The annotated images were split into training, validation, and testing groups using a 7:2:1 ratio. The training stage used data augmentation, which transforms the training data to create a wider range of case images (Jocher et al. 2020). Across some 60 training iterations, of which 38 were usable, as well as the modifications made to the Training Set (Table 2.1), model options and hyperparameters were modified with an aim to improve model accuracy. The key model settings tested in the training phase were model complexity (or size: Small, Medium, or Large), Pre-Trained Weights (PTW), Image Size (ImSz), Batch Size (BchSz), Learning Rate (LR), Weight Decay (WD), and Momentum (M). Training used a freely available, cloud based (Google Colaboratory), high end Graphics Processing Unit (GPU; Tesla K80).

The metric used in this work to determine object detection accuracy is the commonly used mean Average Precision (mAP; Everingham et al. 2015). For each detection, the overlap between the predicted (trained) and ground truth (annotated; validation) is measured by the Intersection over Union (IoU). Precision and recall are calculated based on an IoU threshold; where a prediction is a True Positive (TP) if IoU is equal to or greater than the threshold, otherwise the prediction is False Positive (FP). Precision is the total TP over the total positive results (TP + FP). Recall relies on the number of False Negatives (FN; where the model failed to predict an object) and is the number of TP cases over the sum of total cases (TP + FN). The Average Precision (AP) is the area under the Precision-Recall curve, mAP is the mean of APs per class. mAP@0.5 is the mAP when considering an IoU threshold of 0.5 (50% overlap). Training produces model weights for detection at each epoch and the model weights associated with the maximum mAP@0.5 for each model run were retained. Training of the BPSWL CNN leveraged the PTW from the BP-CP CNN.

Application

The best performing model weights were used in the detection of objects in ~1 million images of Waikeri taken at midday over a 3-year period. The detection model was implemented locally using a relatively modest GPU, a GTX 1080. For each object detected, the model provided a confidence score based on the probability that the box contained a target object. All detected object coordinates were georectified, with the transformation matrix leveraging the GCPs, translated pixel coordinates and water level; the latter of which was tidally adjusted using a local tide gauge.

RESULTS

Training Success was determined by the maximum mAP@0.5 achieved during training. This results section consists of mAP@0.5 values plotted against model training epoch. The maximum mAP@0.5 value for each training run in a plot is included, with colour matched reference lines also showing the epoch of the maximum.

Figure 4 presents three plots to compare the influence of how Training Sets were prepared (Table 2.1). The model settings for each of the cases are the same. Moving from Colour (RGB) to Grayscale (GS) images results in a 5% increase in max mAP@0.5. Expanding the annotated box (comparing Cases 3 and 4 against Case 5, or Training Sets 1 and 2 against 3, see methods) yielded a 24% increase in mAP@0.5. Incorporating the crest up or crest down class identifier decreased mAP@0.5 by ~20% (Case 10 vs Case 11; Training Set 3 against 4). The difference between Case 5 and Case 10 (same Training Set) was the use of a PTW, which had no discernible effect on the max mAP@0.5 (0.64).

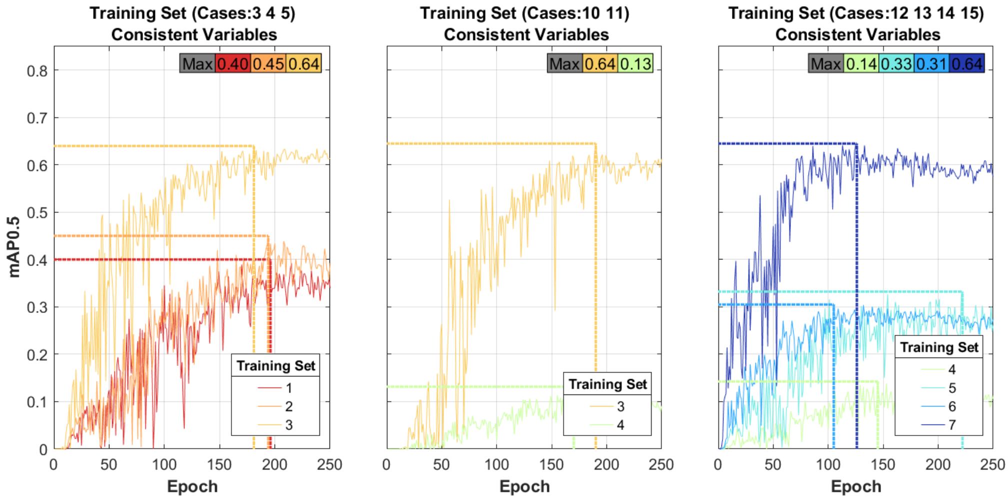


Figure 4. Model training performance plots to compare input training datasets.

Increasing BchSz yields a 1% increase in max mAP@0.5 in two of the three cases (Figure 5). The smaller BchSz results in higher mAP@0.5 values in fewer epochs. Figure 6 illustrates that an image size of 896 pixels (px; in both dimensions) with a small model yields a maximum mAP@0.5 of 0.77, while an image size of 864 px and a medium size model yields a maximum mAP@0.5 of 0.79. The cases used here for model size comparison either vary the PTW, BchSz, or ImSz settings in the model. PTW make little to no difference (1%) to the maximum mAP@0.5 values (Figure 7). Using a BchSz of 80, and a small model, yields the same maximum mAP@0.5 (0.78) as a BchSz of 64 with a larger model (Figure 6). Increasing image size from 640 to 864 increases max mAP@0.5 by 2% (Figure 7).

Maximum mAP@0.5 values have both positive and negative relationships with Learning Rate (LR; Figure 8). Reducing the LR to 1e^{-5} results in a very low maximum mAP@0.5, occurring within 250 epochs. The same training parameters were run to 1000 epochs, yielding 0.5 as the maximum mAP@0.5. The LR 1e^{-4} largely plateaued before reaching 250 epochs. The difference in LR 1e^{-2} and LR 1e^{-4} in later cases (29 and 32) was 1%, with the former yielding a higher maximum mAP@0.5. The LR comparison includes variable momentum. Figure 9 shows that decreasing the value of momentum from 0.937 to 0.7 or 0.5 decreases max mAP@0.5 by ~15%; and including the left-right reversals of images in the Training Set decreases max mAP@0.5 by 1%. Using the model's default Weight Decay

(WD) value of $5e^{-4}$ and Training Set 8, yielded a max mAP@0.5 of 0.63. Increasing WD to $5e^{-2}$ decreases the max mAP@0.5 to 0.59. Decreasing WD by 2, 4, and 6 orders of magnitude results in increases of 1%, 4%, and 3 %, respectively.

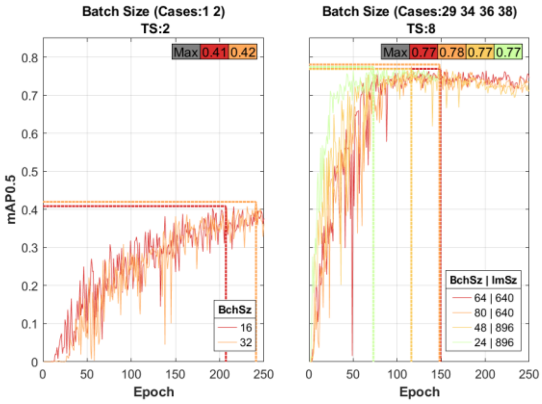


Figure 5. Training performance comparing BchSz.

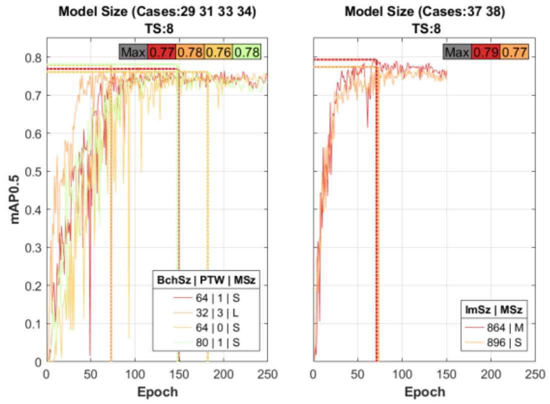


Figure 6. Training performance comparing model size.

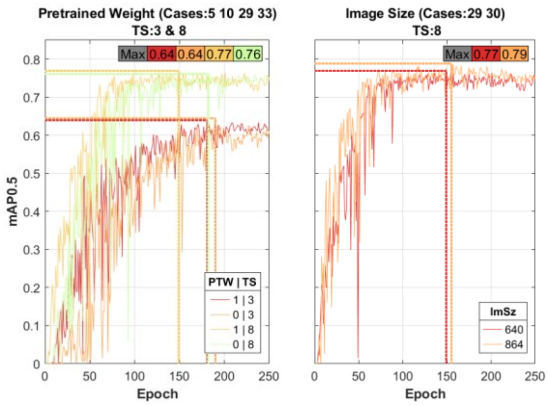


Figure 7. Training performance comparing PTW (left) and image size (right).

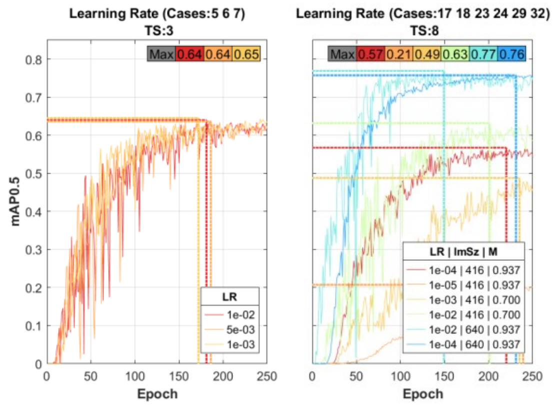


Figure 8. Training performance comparing LR.

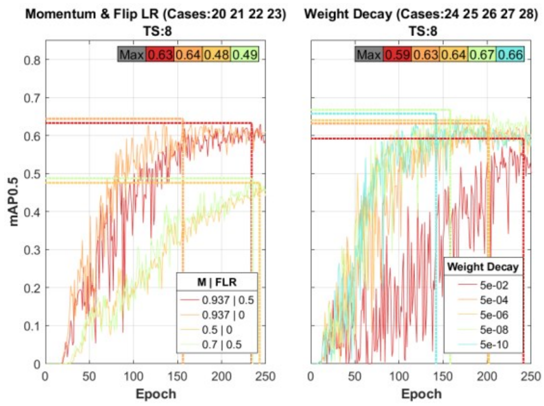


Figure 9. Training performance comparing momentum and FLR (left) and WD (right).

Case 37 yields the highest maximum mAP@0.5 of 0.794 (Figure 6, Figure 10); it uses Training Set 8, default values for LR, M and WD, FLR, a BchSz of 24 (default 16), image size of 864 (default 640) and a medium size model with PTW. Case 30 yielded a max mAP@0.5 of 0.788. The difference between Case 30 and Case 37 is the use of a larger BchSz (64) and a small model. Training of the

BPSWL CNN leveraged the weights from Case 37 with default model settings and achieved a max mAP0.5 of 8.634.

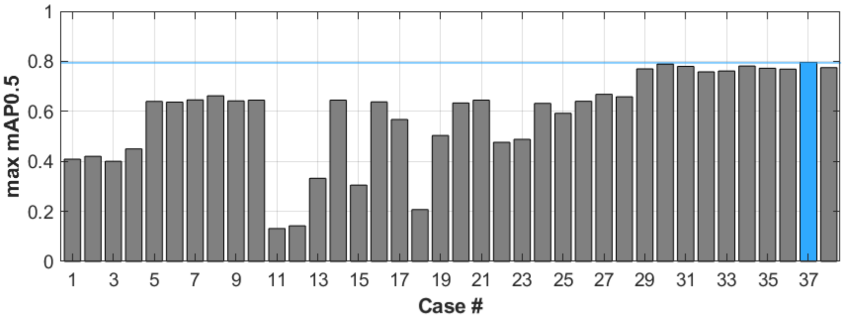


Figure 10. Maximum mAP@0.5 for 38 training cases

Application

The model weights retained from Case 37 were used to detect objects (breaking waves) in ~1 million images. Object detection for a single image occurred in less than 20 milliseconds. Detectable objects were identified in 773,270 of the images, resulting in 1,594,645 break points and crest combinations, each with an associated confidence parameter. Figure 11 demonstrates that confidence is spatially variable and that confidence values range from 0.1 to 0.95. There is a cluster of high confidence values central to the camera's FoV, and an increase in confidence nearer the camera. However, it is not clear if confidence always decreases in the far field as high confidence values are also evident offshore. The boundaries of the FoV appear dominated by low confidence values. The mean confidence value is 0.63, and more than 70% of detections have a confidence value greater than 0.5 (Figure 11).

Peel angle results derived from these detections are presented in detail in Atkin (2021). In summary, the peel angles derived from the automated wave break point and crest detection resulted in average peel angle values that are very comparable to previous studies (Hutt et al. 2001; Scarfe 2008), identified a persistent channel in the seabed and had a peel angle spatial distribution aligned with qualitative descriptions of the surf break (Mead 2000; Scarfe 2008).

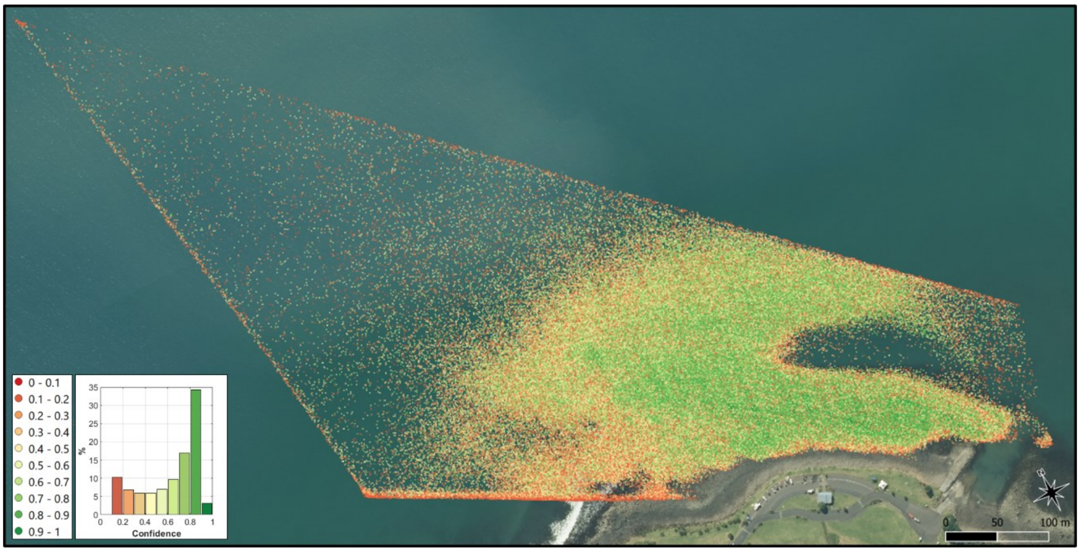


Figure 11. Detected break point confidence. Inset: percentage distribution of confidence values.

DISCUSSION

Of the different model settings and approaches applied to the Training Set in this study, increasing the object detection bounding box had the greatest impact on increasing maximum mAP@0.5. Moving from Colour (RGB) to Grayscale (GS) images provided a 5% increase in max mAP@0.5. These precision gains are also associated with a reduction in memory allocation, model run time and/or cloud based/network overheads. The improvements in mAP@0.5 made through modification of the Training Set demonstrates the importance of data preparation, which aligns with labelling accuracy being considered the most important component of model performance (e.g., Karimi et al. 2020).

Jocher et al. (2020) indicate that the number of images per class should be no less than 1,500 and that there should be 10,000 or more instances (objects) within the Training Set. Only 3,717 instances were used in this study. Labelling of all instances is also encouraged; however, not all breaking waves were considered surfable, and a clear distinction of what the neural network is trying to achieve, surfability or wave tracking, is required. By virtue of not being able to effectively label the surfing part of the wave, during inclement conditions, a basic surfability threshold or surfing wave quality filter neural network has been developed. In its current state however, the neural network is likely to flag those times where glare from the sun prevented annotation as unsurfable conditions.

Model and image size have also been shown to have a big effect on model training performance. While different model sizes are available, and the results indicate that a larger model will provide higher mAP@0.5 maximums, the choice of model size in this study was limited by the hardware available. A direct model size comparison (all other model settings constant) was not undertaken during the study as the assumption was made that increasing model size would yield higher maximum mAP@0.5 values. The comparison of model size is not direct, either PTW, BchSz or ImSz changes between cases. PTW made little to no difference. A BchSz of 80 and a small model yields the same maximum mAP@0.5 as a BchSz of 64 with a large model, increasing ImSz from 640 px to 864 px increases max mAP@0.5 by 2%. The results provide a good example of the trade-off between model and image size (limited by hardware). BPSWL detection could be improved by using sub-images determined by the BP-CP detection. Using subset images means a higher resolution image could be used in training and/or a larger model.

There is scope for improvement on an essentially well-functioning application of machine learning. While this study was largely focussed on iterating through model settings, Jocher et al. (2020) provide a hyperparameter evolution method, which could be explored in future studies. Improvements to the spatial distribution of confidence values should also be considered. The dominance of low confidence detections on the left-hand side of the RCS FoV, or southern edge of the spatial extent of data in real world coordinates, are attributed to the lack of pixel information to the left of the breakpoint, with training objects including equal extents of the broken and unbroken parts of the wave either side of the Instantaneous Break Point (BP). For confidence in post-processing of detections it may be judicious to exclude points on the FoV boundary, or within a boundary buffer zone related to the width of bounding boxes.

The training set developed in this work is focused on a single surf break. While a wide range of conditions have been captured, a more generic Training Set could be compiled by using not only other RCS systems (e.g., Atkin et al. 2017), but also more commercial surf cameras and/or general images of breaking waves. This could be developed by a wider group of contributors, like the popular baseline training datasets (e.g., Lin et al. 2014), and become effective in a wide range of settings, or develop wave breakpoint and crest specific PTWs. Of relevance to this is the observation that negating the augmentation of vertical mirroring of images (only left-handers) marginally increases max mAP@0.5. The inclusion of both left- and right-hand breaking waves would open up the applicability of this model, especially at more dynamic sites where breaking is less predictable, such as beach breaks.

A restriction included in the method was the omission of any wave where the CP is higher in the image than the BP. This assumption was implemented to bypass the poor performance of the Training Set where a class was included to distinguish relative CP location. The assumption is considered valid, with 98.8% of cases conforming, and excluding the minority (crest above break point) is not a concern in post processing given the frequency of data collection and, therefore, overall points available. However, an approach that may be more holistic is to include a box rotation parameter in the object labelling of the Training Set (e.g., Edeyejedi 2020). The BP could remain central to the object, as the expanded box improved model performance significantly. The crest orientation would be depicted by a box's major axis. The application may also yield better results from bounding circles, over boxes (e.g., Yang et al. 2020). A different model framework may be required for this, and this particular model was chosen for being open source, the quickest object detection model available, and a lightweight framework that could be eventually implemented on low compute RCS.

Being able to quantitatively establish a natural baseline of a coastal resource, such as a surf break, is of great benefit to sustainable management practices. This approach could be readily replicated at other sites; furthermore the application of machine learning for monitoring of coastal hazards could readily be incorporated into the same system, especially given the speed of detection, which lends itself to real-time monitoring. This application could also be used in live streams of surfing competitions to provide an extra element of analysis, which is encouraged by the rapid detection of multiple objects using a modest GPU.

SUMMARY

The wave breaking characteristic of peel angle is an imperative metric of surfing wave quality and requires data about the path of the broken wave and orientation of the unbroken wave crest. This work considered the application of machine learning techniques to automate the detection, in oblique images collected by a remote camera system, of the instantaneous break point and unbroken crest of waves at Waikeri on the west coast of Aotearoa New Zealand.

While recent work has shown the application of machine learning in surfing amenity, to the authors' knowledge this is the first application of machine learning to detect the fundamental components required to derive peel angle and meaningful surfing wave quality monitoring. While there is scope to improve the model, it has shown rapid and accurate detection capability of an extremely dynamic phenomenon over a high frequency, medium term dataset. This capability has far-reaching potential benefits or the establishment of natural baselines and in the sustainable management of surfing resources.

ACKNOWLEDGMENTS

All work reliant on remote camera systems would never be possible without the generosity of the site hosts, to whom we will always be indebted. The enthusiasm of Amardeep Singh while introducing options for computer vision and object detection, and the ongoing support of Professor Karin Bryan of the University of Waikato are greatly appreciated.

REFERENCES

Atkin, E.A. 2010. *The Impact of an ASR on Breaking Wave Conditions at Boscombe*, UK. Thesis: University of Southampton, UK.

Atkin, E.A. 2021. Machine-learned Peel Angles for Surfing Wave Quality Monitoring. *Proceedings of the 25th Australasian Coasts & Ports 2021 Conference*, Christchurch, New Zealand.

Atkin, E.A., Mead, S.T., Bryan, K., Hume, T. and Waiti, J. 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. *Proceedings of the 23rd Australasian Coasts and Ports Conference*, Cairns, Aus., 21-23 June 2017.

Atkin, E.A, Bryan, K., Hume, T., Mead, S. T., and Waiti, J., 2019a. *Management Guidelines for Surfing Resources*. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research.

Atkin, E.A, Bryan, K., Mead, S. T., Hume, T., and Waiti, J. 2019b. Management Guidelines for Surfing Resources. *Proceedings of the 24th Australasian Coasts and Ports Conference*, Hobart, Australia, 10-13 September 2019.

Atkin, E.A., Mead, S.T., O'Connell-Milne, S. and Davies-Campbell, J. 2021. *Surf Break of Regional Significance*: Southland. eCoast technical report prepared for Environment Southland.

Battjes, J. A. 1974. Surf Similarity. *Coastal Engineering Proceedings*, 1(14), 26.

Bouguet J.Y. 2015. Camera Calibration. Toolbox for Matlab. Available online: http://www.vision.caltech.edu/bouguetj/calib_doc/index.html

Bruder, B.L. and Brodie, K.L. 2020. CIRN Quantitative Coastal Imaging Toolbox. *SoftwareX*, 12.

Davies-Campbell, J. 2018. *The Morphology and Surf Conditions of Aramoana Beach, Otago : A Surf Break of National Significance*. Thesis: University of Waikato, Aotearoa New Zealand.

Department of Conservation, 2010. *New Zealand Coastal Policy Statement 2010*. Wellington, New Zealand: Department of Conservation, 30p.

Edeyejedi 2020. Re: *Rotated Bounding Boxes* [Discussion post]. GitHub. https://github.com/ultralytics/yolov5/issues/510

Everingham, M., Eslami, S. M. A., Van Gool, L., Williams, C. K. I., Winn, J. and Zisserman, A. 2015. The PASCAL Visual Object Classes Challenge: A Retrospective. *International Journal of Computer Vision*, 111(1), 98-136.

Galvin, C. J., 1968. Breaker Type Classification on Three Laboratory Beaches. *Journal of Geophysical Research,* 73, 3651-3659.

Guizar-Sicairos, M., Thurman, S.T. and Fienup, J.R. 2008. Efficient Subpixel Image Registration Algorithms. *Optics Letters*, 33, 156-158.

He, K., Gkioxari, G., Dollár, P. and Girshick, R. 2017. Mask R-CNN. *In Proceedings of the IEEE International Conference on Computer Vision*.

Holman, R.A and Stanley, J. 2007. The History and Technical Capabilities Of Argus. *Coastal Engineering*, 54, 6, p. 477–491.

Hutt, J. A., Black, K. P. and Mead, S. T. 2001. Classification of Surf Breaks in Relation to Surfing Skill. In: *Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research*, SI No. 29, p. 66-81.

Iribarren, C. R., and Nogales, C. 1949. *Protection des Ports. Section II, Comm. 4, XVIIth Inter. Naval Cong.*, 31-80.

Jocher et al. 2020. *Ultralytics/yolov5.* Version v3.0. DOI: 10.5281/zenodo.3983579

Karimi, D., Dou, H., Warfield, S.K. and Gholipour, A. 2020. Deep Learning with Noisy Labels: Exploring Techniques and Remedies *Medical Image Analysis*, 65.

Kim, J., Kim, J., Kim, T., Huh, D., and Caires, S. 2020. Wave-Tracking in the Surf Zone Using Coastal Video Imagery with Deep Neural Networks. *Atmosphere*, 11(3), 304.

Li, M., Zhang, X., Lei, L., Wang, X. and Guo, X. 2020. Agricultural Greenhouses Detection in High Resolution Satellite Images Based on Convolutional Neural Networks: Comparison of Faster R-CNN, YOLO v3 and SSD. *Sensors*, 20, 4938.

Lin, T.Y., Maire, M., Belongie, S., Hays, J., Perona, P., Ramanan, D., Dollár, P. and Zitnick, C.L. 2014. Microsoft COCO: Common Objects in Context. *European Conference on Computer Vision*, p.740-755.

Malta, A., Mendes, M. and Farinha, T. 2021. Augmented Reality Maintenance Assistant Using YOLOv5. *Applied Sciences*, 11, 4758.

McIntosh, R., Atkin, E.A. and Davies-Campbell, J, 2018. Development of an Automated Peel Angle Detection System for the Manu Bay Surf Break. *New Zealand Coastal Society Conference*, Gisborne, 2018.

Mead, S.T. 2000. *Incorporating High-Quality Surfing Breaks into Multi-Purpose Offshore Reefs*. Hamilton, New Zealand: University of Waikato, Ph.D. dissertation.

Mead, S. T. and Black, K. P. 2001a. Field Studies Leading to the Bathymetric Classification of World-Class Surfing Breaks. In: *Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research*, SI 29, pp. 5-21.

Mead, S. T. and Black, K. P. 2001b. Functional Component Configurations Controlling Surfing Wave Quality at World-Class Surfing Breaks. In: *Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research*, SI 29, pp. 22-32.

Mead S. T. and Black, K. P. 2001c. Predicting the Breaking Intensity of Surfing waves. In: *Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research*, SI 29, pp. 51-65.

Moores, A. 2001. *Using Video Images to Quantify Wave Sections and Surfer Parameters*. Hamilton, New Zealand: The University of Waikato, Masters Thesis, 143p.

Nepal, U. and Eslamiat, H. 2022. Comparing YOLOv3, YOLOv4 and YOLOv5 for Autonomous Landing Spot Detection in Faulty UAVs. *Sensors*, 22, 464.

Rodriguez-Padilla, I., Castelle, B., Marieu, V. and Morichon, D. 2020. A Simple and Efficient Image Stabilization Method for Coastal Monitoring Video Systems. *Remote Sensing*, 12, 70.

Scarfe, B.E. 1999. *Hydrography and Photogrammetry: Tools for Artificial Surfing Reef Studies*. MSc Dissertation, University of Otago, New Zealand.

Scarfe, B. 2008. *Oceanographic Considerations for the Management and Protection of Surfing Breaks*. PhD thesis, University of Waikato, New Zealand.

Shand, T.D. Bailey, D.G., and Shand, R.D. 2012. Automated Detection of Breaking Wave Height Technique. *Journal of Coastal Research*, 28(3), 671-682.

Stringari, C.E., Harris, D.L. and Power, H. 2019. A Novel Machine Learning Algorithm for Tracking Remotely Sensed Waves in The Surf Zone. *Coastal Engineering*,147, p.149-158.

Stringari, C.E, Guimarães, P.V, Filipot, J-F., Leckler, F. and Duarte, R. 2021. Deep Neural Networks for Active Wave Breaking Classification. *Scientific Reports*, 11(1), pp.1-12.

Thompson, M.E., Watterson, E. and Baldock, T.E. 2021. Detailed Assessment of Surf Amenity over Reef and Sand Bottom Surf Breaks using Wave Peel Tracking. *Proceedings of the 25th Australasian Coasts & Ports 2021 Conference* – Christchurch, 30 November – 3 December 2021.

van der Walt, S., Schönberger, J.L., Nunez-Iglesias, J., Boulogne, F., Warner, J.D., Yager, N., Gouillart, E., Yu, T. and the scikit-image contributors 2014. scikit-image: Image processing in Python. *PeerJ*, 2, 453.

Walker, J.R., Palmer, R.Q. and Kukea, J.K. 1972. Recreational Surfing on Hawaiian Reefs. *Proceedings of the 13th Conference on Coastal Engineering*, Vancouver, Canada.

Walker, J.R., 1974, *Recreational Surf Parameters*, Honolulu, Hawaii, USA: University of Hawaii, Look Laboratory Report No. 30, 311p.

Wiegel, R. L., 1964. *Oceanographical Engineering*. N.J: Prentice-Hall.

Yang, H., Deng R., Lu, Y., Z, Zhu, Chen, Y., Roland, J.T., Lu, L., Landman, B.A., Fogo, A.B. and Huo, Y., 2020. CircleNet: Anchor-free Glomerulus Detection with Circle Representation. Medical image computing and computer-assisted intervention, *International Conference on Medical Image Computing and Computer-Assisted Intervention*.

9 Machine-learned Peel Angles for Surfing Wave Quality Monitoring

Publication details:

Atkin, E.A., 2021. Machine-learned Peel Angles for Surfing Wave Quality Monitoring. In Proceedings of the 25th Australasian Coasts and Ports Conference – Christchurch, New Aotearoa Zealand, 11-13 April 2022.

This paper applies the machine learning capability described in Chapter 8 to establish spatially and temporarily variable calculations of the surfing wave quality parameter of peel angle at Manu Bay. This work expands of previous studies that relied on either manual or computationally expensive methods for establishing a quantitative baseline. This work presents a novel technique that supports the consistent theme of the Guidelines about understanding resources and establishing baselines.

Machine-learned Peel Angles for Surfing Wave Quality Monitoring

Edward A. Atkin[1,2,3,4]
[1] eCoast Marine Consulting and Research, Whaingaroa, New Zealand; e.atkin@ecoast.co.nz
[2] University of Waikato, Hamilton, New Zealand
[3] Aotearoa New Zealand Association for Surfing Research
[4] International Association of Surfing Research

Abstract
Aotearoa New Zealand's environmental management framework recognises surf breaks as coastal resources. Sustainable coastal management benefits from establishing natural baselines to characterise resources. The dynamism and subjective evaluation of surfing, combined with a paucity of physical datasets, makes it difficult to establish a quantitative baseline.

Remote Camera Systems (RCSs) are used by coastal scientists to monitor physical process and parameters. RCSs collect large amounts of repeatable data for a low overhead labour input. This research leverages data collected from an RCS with a field of view of Waikeri (Manu Bay), a Surf Break of National Significance. The camera system collects 1200 images every hour, each day during daylight hours. The data used in this work comprises ~1 million images taken at midday over 3 years. A data subset was used to train a Fully Convolutional Neural Network (FCNN) to automatically detect wave breaking patterns, including the wave break point and unbroken wave crest orientation. From the dataset more than 750,000 images contained functional data. The FCCN targeted more than 1.5 million break points and wave crests, each with an associated confidence parameter. Post processing steps included the georectification of targets with a transformation matrix leveraging ground control points, and the derivation of each break points peel angle – a key quantitative parameter of surfing wave quality associated with the speed at which a wave breaks laterally along its crest. The peel angles were evaluated against coincident tide and wave statistics.

This work established a medium-term quantitative baseline of surfing wave quality for Waikeri using a remote camera monitoring system and a trained FCNN. In terms of quantitative and meaningful surfing wave quality monitoring, this is the first application of this technology combination. This approach can be readily replicated at other sites to aid in the sustainable management of surfing resources.

Keywords: Surfing wave quality, surf break, peel angle, machine learning, resource management.

1. Introduction

Surfing resources have a range of values and contribute to the natural character and landscape of the coastline, have high recreational, cultural, and amenity values, and provide a distinct subsector of the tourism industry. As such, in Aotearoa New Zealand surfing resources are recognised by the statutory instruments. The Resource Management Act (1991) and the New Zealand Coastal Policy Statement (NZCPS), which under the RMA is mandatory, are both key. The 17 Surf Breaks of National Significance (SBNS), designated under the NZCPS, cumulatively occupy approximately 4.5 km of coast, 0.0003 % of the Aotearoa New Zealand coastline.

The sustainable management of surfing resources has become the focus of coastal planning throughout Aotearoa New Zealand at a full range of municipal levels. Sustainable resource management benefits from establishing natural baselines to characterise resources and ongoing monitoring. The dynamism and subjective evaluation of surfing, combined with a paucity of physical datasets, makes it difficult to establish a quantitative baseline.

Of the quantifiable physical characteristics of surf breaks [16], peel angle (α) lends itself most readily to monitoring. The peel angle was originally described as the angle between the trail of broken white water and the crest of the unbroken part of the wave [23]; is directly related to the rate that the breaking part of the wave translates laterally and has been evaluated against skill levels [13]. Earlier research recognized the value of aerial photographs for measuring peel angles [13,17,18,19,24], and the advent of readily available repeat satellite imagery provides more cost effective and temporal opportunities [*e.g.,* 3,5]. Despite this, these data sources only offer snapshots in both time and space.

Previous investigations have recognised the value of shoreline based oblique photogrammetry for surf break assessments [20,22], and early efforts to monitor a Multi-Purpose Reef in Boscombe, UK and derive peel angle from geo-rectified imagery yielded meaningful results [1]. This was however, at the expense of many hours in the field and many more manually measuring peel angles from geo-rectified images.

Remote Camera Systems (RCSs) have been employed by coastal scientists and researchers for many years [12] to monitor physical process and parameters. RCSs collect repeatable data for a low overhead labour input, and are capable of high frequency data collection – which ideally suited for studying ephemeral physical phenomena such as individual breaking waves. In 2017, a research program focused on addressing the lack of clear quantitative measures or guidelines describing the characteristics and functionality of a surf break [2,3,4]. As part of this project 5 RCS were set up, including one at Waikeri (Manu Bay), on the west coast of Aotearoa New Zealand's North Island (Figure 1). The RCS collects 1200 images @ 1 Hz every hour, each day during daylight hours.

Figure 1 Study site location. Map insert shows national location. White circle: location of wave climate data extraction. Yellow box: Waikeri. Red circle: RCS location. The large, vegetated area south of Waikeri is Mt Karioi.

As part of the research project an automated system was developed to measure peel angle angles from geo-rectified images [15]. While the automated system provided comparable results to manual measurement efforts, the system was compute-intensive. It relied on pixel intensity gradient methods [7,10], iterative search and refine techniques and ultimately filtering for outliers of the final dataset.

A Fully Convolutional Neural Network (FCNN), object detection model [14] is employed to analyse ~1 million images taken at midday between May 2017 and June 2020. Model development used a pool of ~2000 images with a 70-20-10 train-valid-test split. All instances of surfable breaking waves in each image were annotated with breakpoint and crest location. Development of the model to automatically detect wave break points and unbroken wave crest orientation [6] included more than 60 training runs that considered different combinations of annotations (*e.g.*, crest length), model complexity, pretrained weights, epoch size, image sizes, batch size and hyperparameters. Object detection by the model occurs in less than 20 milliseconds on a low-end graphics processing unit. Of the ~1 million images, 773,270 yielded detectable objects, amassing 1,594,645 break points and crest combinations each with an associated confidence parameter. A wave tracking algorithm, considering detection confidence vales of 0.5 and above, yielded to 117,540 individual peeling waves (consecutive break point clusters) comprising of 665,520 break points.

Figure 2 provides an example of consecutive images RCS with traced breakpoints and crests from the FCNN, with post-processed peel angle values. Waikeri is a long point break [16], breaking on, and adjacent to, a fan-shaped andesitic boulder field that abuts black titano-magnetite sand [2] on the northern side of Mt Karioi on Aotearoa's west coast. The western end of the point consists of a mesoscale scale wedge, with a superimposed ridge at the western end of the point [18,22], this area known as "The Ledge", is where waves break in a fast and hollow manner. From aerial photographs, measured peel angles at Waikeri have been shown to be between 30-75°, with lower (faster breaking) angles across "The Ledge" and increasing thereafter; peel angles have been shown to vary along the length of the surfable wave; mean peel angle was reported as 65° [13,22].

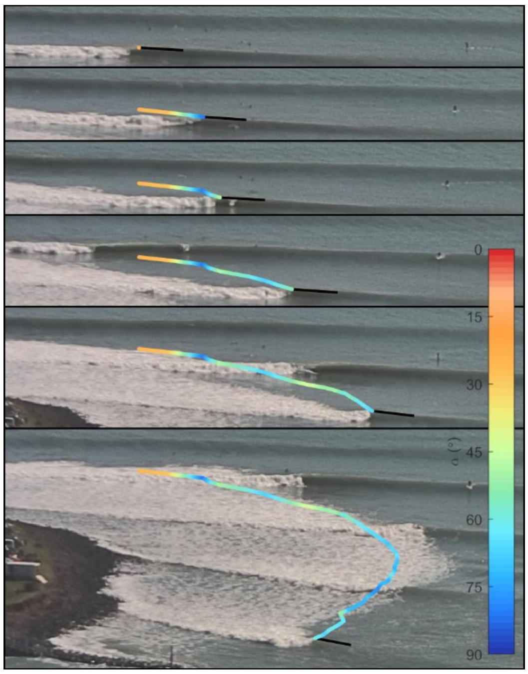


Figure 2 Example to show part of the field of view of the RCS, with automated break point detection and crestline, wave tracking and peel angle. This set is from the 3rd of May 2018 during modest conditions 2.2 m @ 12.2 s from 236°.

This work calculates and evaluates peel angle against coincident tide, wind, and wave statistics; whilst establishing a medium-term quantitative baseline of surfing wave quality for Waikeri.

2. Methods

Pre-processing steps included image registration [*e.g.,* 21], to account for camera movement and allow accurate geo-rectification, detection through the FCCN and the development of a breaking point tracking algorithm and filtering techniques [6].

Post processing steps included the georectification of targets with a transformation matrix leveraging ground control points measure with RTK GPS [2], and the derivation of each break points peel angle. Peel angle was calculated for each time stamped breakpoint using the dot product of the vectors representing waves crest and for both the preceding and following breakpoint position. This provided a mean value for α, no differences between the forward and backward measurements were apparent. From the breakpoint locations, along track breaking length and maximum speed were calculated. Given the abundance of data point, the number of individual waves and break points were further reduced by omitting waves of less than 3 points (seconds), and any waves containing with α values of less than 0° or greater 90°. The final data set consisted of 100,517 waves comprising 533,100 data points.

Between May 2017 and June 2020, the environmental parameters of Significant Wave Height (H_s), Mean Wave Period (T_m), Mean wave Direction (D_m), Hs of total swell (H_{sts}), Tm of total swell (T_{mts}), D_m of total swell (D_{mts}), H_s of wind waves (H_{sww}), T_m of wind waves (T_{mww}), D_m of wind waves (D_{mww}), and wind speed and direction where extracted every hour between from a 0.5° resolution global re-analysis [11]. Tidal water levels were predicted every minute form a 1/12° model [9]. The tide, wind and wave data were extracted from -37.76, 174.74, 9 km north-northwest of Waikeri (Manu Bay). Each time stamped break point was assigned a value for each environmental parameter through spline interpolation.

Basic statistics were first calculated to characterise the study site. Cross correlations of dependent to independent variables were undertaken, with thresholds of wave height and period for inclusion in the analysis. To determine if spatial relationships between α and independent variables exist, the data was binned at 25 m^2 with regression of each variable in each bin; then secondary binning of water level (wl) bins: wl <=-0.95 | -0.95 < wl <=0 | 0< wl l <=0.95 | 0.95 < wl; where water level is in metres relative to Mean Sea Level; isolating low tide, low to mid, mid to high and high tide conditions. Populations of less than 10 were discarded. In each bin, statistics of α and a correlation with independent variables was calculated.

3. Results

Figure 3 shows geolocated breakpoints overlain on a georeferenced aerial photo. The data has good spatial coverage and exhibits a full range of α. In general terms, lower values for α occur at the western end of the point, and high values in the eastern end. Close to shore at the eastern end there is a spatially consist area of α, ~40°. There is a lack of data in a ~200 m long area, starting ~50 m north of the breakwater, creating a northern arm and southern arm to the break point spatial distribution. The insert of Figure 3 shows a depression in the bathymetry [2] in this area; the bathymetric data was collected on the 26th of August 2017.

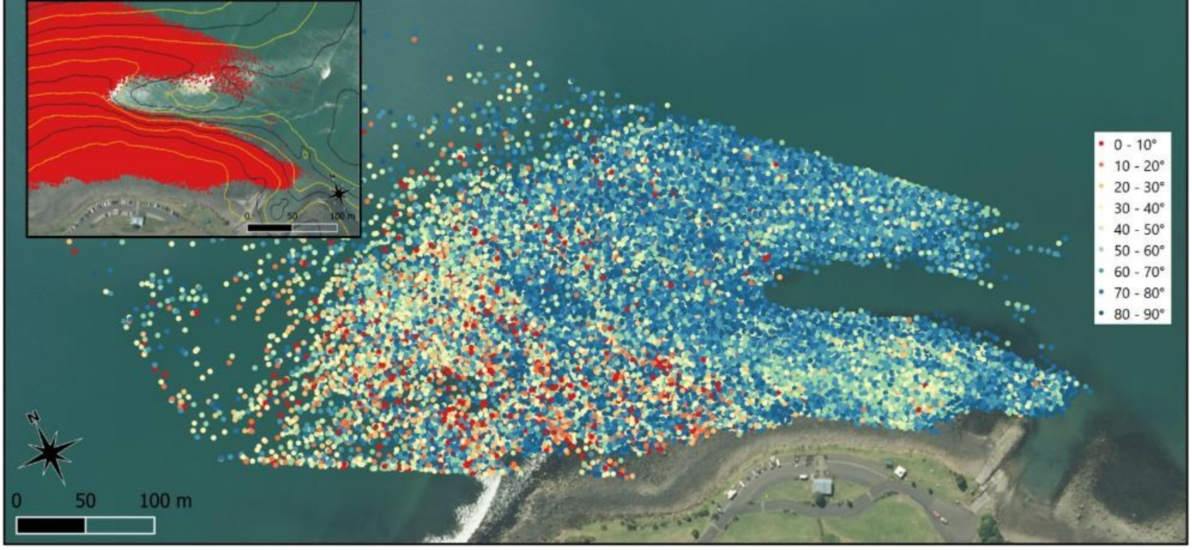


Figure 3 Filtered surfable break points detected between May 2017 and June 2020; colour graduated based on peel angle. The insert shows the same breakpoint locations with a depth isobath overlay. The nearest contour to land is -0.5 m (MSL), contours are in 1 m increments.

The mean α for the entire dataset is 60.0°, and 61.2°, 59.5°, 59.9°, 60.9° for low to high tide bins, respectively. A full range of α values (0°-90°; Figure 4) are apparent in all tidal subsets. Lower α are generally observed closer to the shoreline and to the western end of the point (Figure 4). In the low to mid tide subset there is a small area close to shore, mid-way along the point, of low mean α values, around 30°.

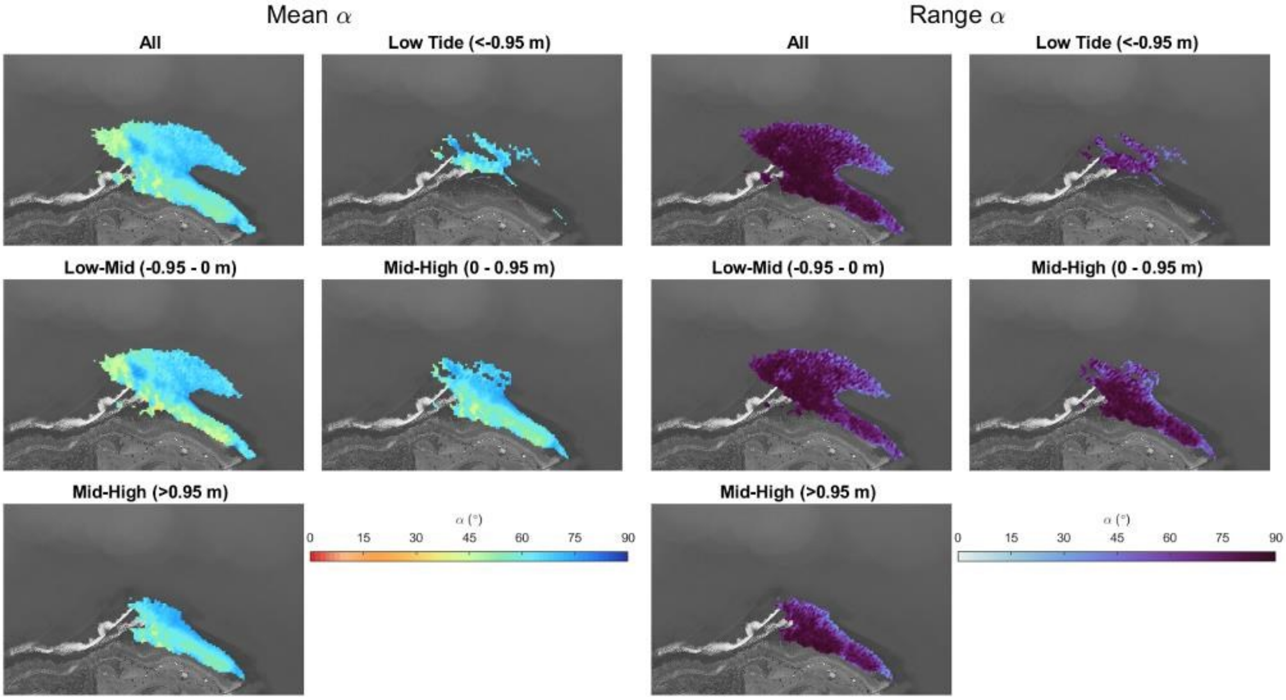


Figure 4 Mean peel angle (left) and range (right) in 25m^2 bins for all tidal heights (top left) and the 4 tidal water level bins.

Cross correlations of all parameters against the dependent α yielded no significant results. The largest correlation coefficient (r) values of ~0.1 were for tide and H_{sww}. Limiting the analysis of data to a range of H_s and T_m (full sea, wind, and swell variations) offered no increase. The data set was simplified by integrating α over time using the daily time blocks. A cross correlation of this dataset provided {negative} coefficients of -0.24, -0.16 and -0.14 for S_{dww} H_{sww} and T_{mww}, respectively; and {positive} coefficients of 0.22, 0.17m, 0.16, 0.15, for T_m, tide, T_{mts} and H_{sts}, respectively.

Considering all data (no wl binning), tide exhibits a relatively strong relationship to α, with r values reaching 0.6, and consistently >0.3 through the inner section of the point (Figure 5). Of the tidally binned data, only the lower tide results exhibit a spatially consistent correlation with tide, and more so with the low to mid tide data set. The Highwater levels shows little spatial consistency.

From Figure 6, H_s and H_{sts} show spatially consistent positive coefficients of ~0.5 around the inner section of the point; and weak, sporadic, but abundant, negative correlations in the offshore and western areas. The positive relationship on the inner point diminishes with increasing tide.

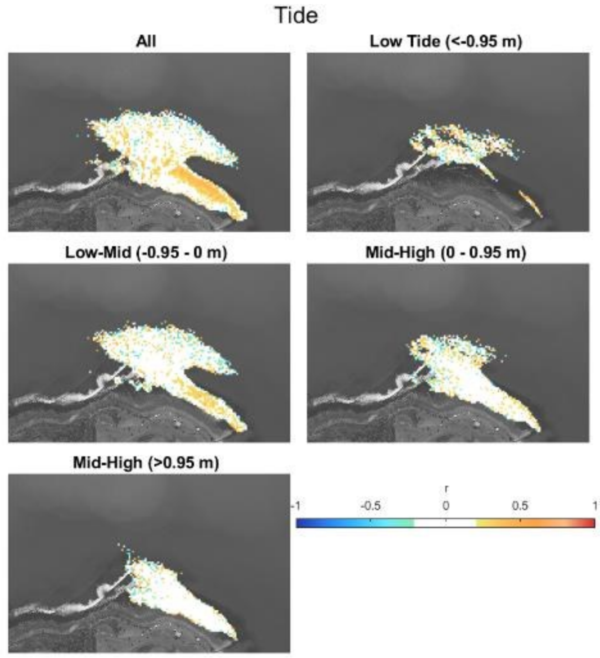


Figure 5 Correlation coefficients between predicted tidal water levels and peel angle in 25m^2 bins.

When considering all tides and low to mid tide, T_m and T_{mts} exhibit positive coefficients with the northern arm, and some consistency along the sand/boulder interface of the southern arm (Figure°7). At low tide there are widespread, negative correlation values (↑T_m ≈ ↓α) at the offshore/western end. These relationships are not consistent with T_{mww}. The wind wave correlations, for all wave variables were, in general, very poor. Correlations with wind speed and direction yielded no noteworthy results.

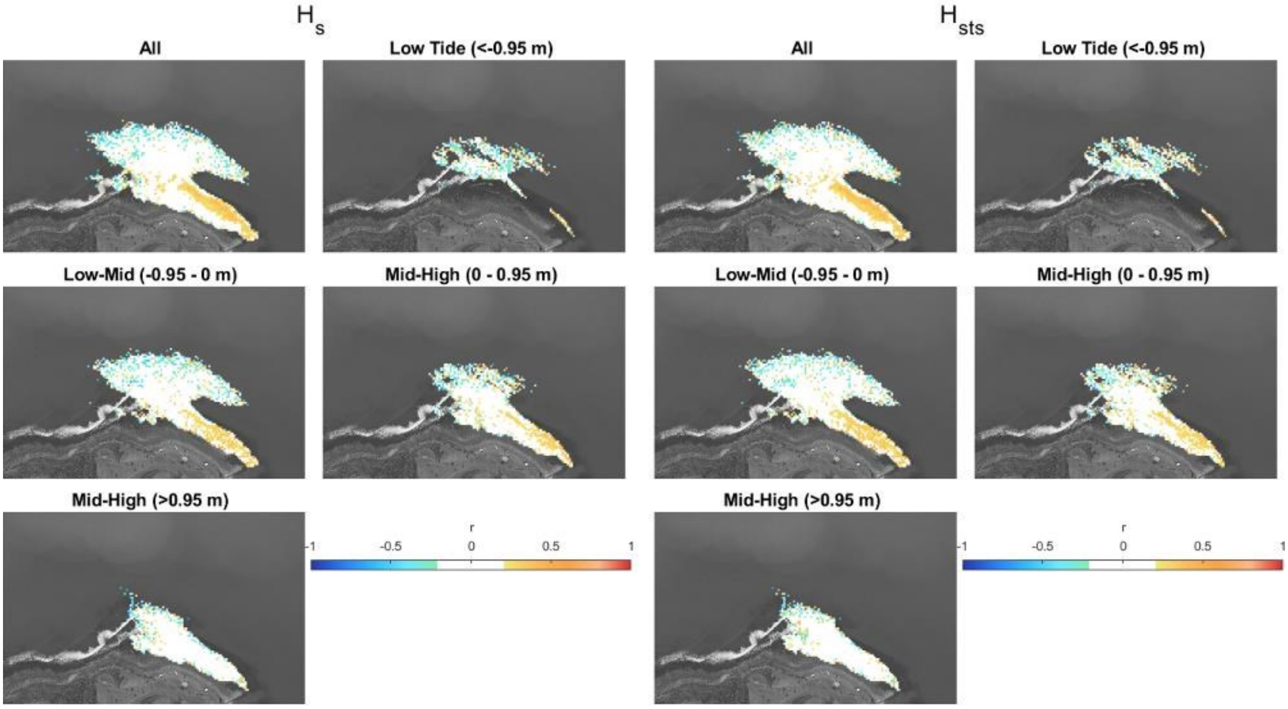


Figure 6 Correlation coefficients between H_s (left) and peel angle and H_{sts} (right) and peel angle in 25m^2 bins for all tidal heights (top left) and the 4 tidal water level bins.

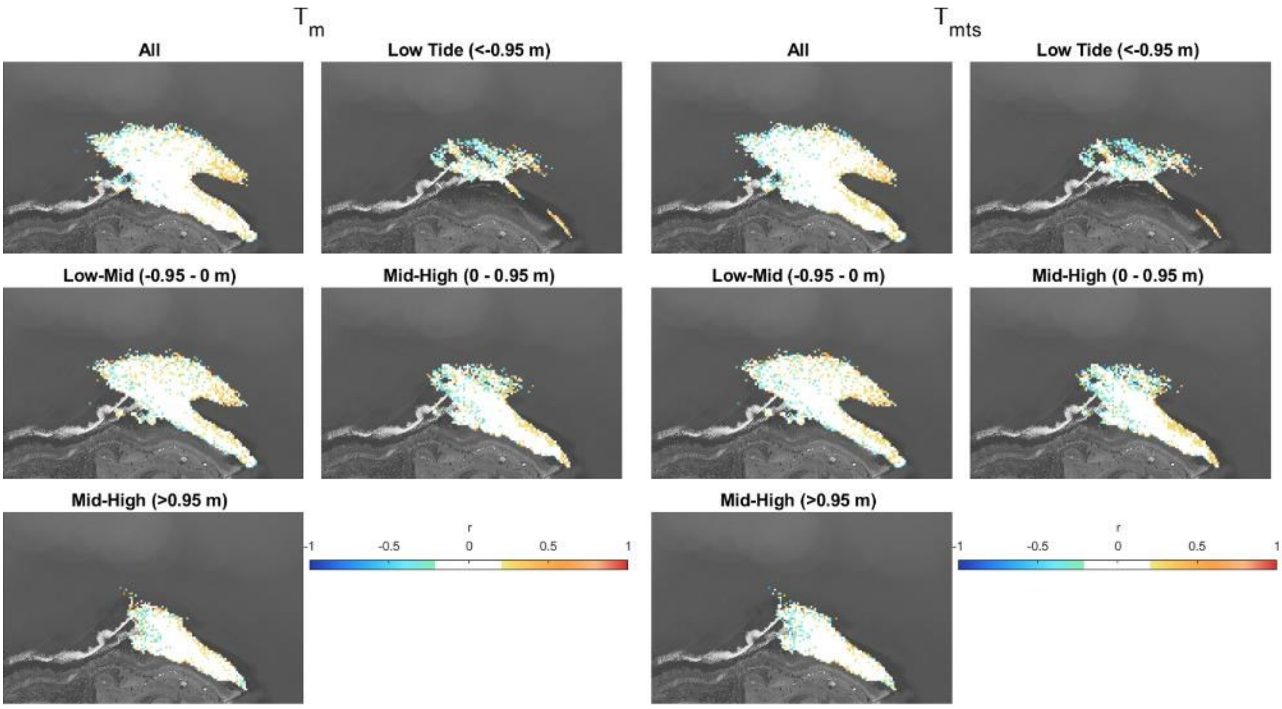


Figure 7 Correlation coefficients between peel angle and T_m (left) T_{mts} (right) in 25m^2 bins for all tidal heights (top left) and the 4 tidal water level bins.

4. Discussion

Analysis of the breakpoint dataset identified a large area at the eastern end of the point where surfable wave breaking does not occur. This area aligns with a depression in the bathymetry. Given that the hydrographic survey was undertaken ~3 months after the start of the data collection period, the lack of breakpoints in the dataset being consistent through to June 2020, indicates that this seabed feature is persistent.

The mean α estimate 60° is less than, but comparable to, that estimated in previous studies (65°); the range of observed α is wider: 0°-90°, compared to 30°-75° [13]. The offset between mean α values could be a product of previous work focusing on certain surfable conditions, whereas this work consider a wide range of conditions. The fact the two mean values are so close is likely to be a testament to the consistency of the surf break to deliver surfable peel angles and likely a function of the preconditioning that aligns wave crest to more favourable orthogonal directions [18,19].

The results indicate lower mean α values at the western end of the point, increasing along the length of the point to the east, which is consistent with observations of The Ledge, where faster breaking occurs [13]. Bin population reduces when the data set is constrained to lower tides, which is a time associated with surfability at The Ledge. Alterations to water level bins may provide more clarity around the influence of independent variables on The Ledge.

This work did not identify a significant correlation between α and wave direction variables, which could again be testament to affective offshore preconditioning of waves to the favoured orthogonal direction. The correlation with tide is stronger on the inner section of the point. In addition to tide, the inner point shows the most notable relationship to the environmental variables of H_s, H_{sts}, T_m, and T_{mts}. However, the correlations are not significant.

In theory, both wave height and period can correlate with peel angle positively and negatively. Increasing period will align wave orthogonals to depth contours, which will reduce peel angle (negative correlation), however a longer period wave has the potential to break in deepwater as a function of wave height, reducing the time and space to refract, thus increasing peel angle (negative correlation). The permutations for wave height and period combinations and their influence on peel angle really need to be considered in the context of both depth and seabed gradient.

Preliminary investigations to restrict analysis to a dataset from the area on the inside of the point (that has shown some correlation), limiting the wave period to those greater than 10 s, wave heights to those greater than 1 m and less than 3 m, water levels to low-mid, and wind speeds to less than 5°ms^{-1}, yields improvements in area based coefficients with r values of 0.34 and 0.29 for tide and wave height, respectively.

Correlation analysis has used a linear model to identify relationships between peel angle and environmental variables. Peel angle itself is a function of wave propagation in the nearshore and breaking, which are nonlinear processes. Nonlinear regression and multivariate analysis may reveal more meaningful relationships. In addition, improvement and potential research steps could consider narrowing the analysis down spatially to other discrete areas (*e.g.,* The Ledge) and/or binning the incident wave climate, and/or targeting a ranges of peel angles. This work has not covered ride length, section length or wave breaking speed in any detail. While these parameters are not surfing wave quality indicators, they are subjective qualities that surfers look for in a surf break and should certainly be assessed with this dataset against other published works [*e.g.*, 19,20], and compared to environmental variables.

The wave data used here is some 9 km from the study site at an exposed location. The large headland of Mt Karioi acts to precondition not only wave crests, but also acts as a high frequency filter during the predominant south-westerly conditions [16]. More site specific met-ocean variables with a higher temporal resolution and narrowed spectral width, such as that which could be retrieved from a higher resolution spectral wave model, may yield more significant correlations. In addition, the water level data is predicted from a model based on tidal harmonics. A local water level, which would include barometric and other non-tidal water level signals, may help resolve any relationships.

What this investigation does provide is a first attempt at spatially characterising peel angle at a surf break, which is substantial step toward a standard of establishing a quantitative environmental baseline for surf breaks. The data collection method, and the speed of detection, lends itself to real-time surfing wave quality monitoring, using the tracking algorithm to create, report and record a peel angle product – as opposed to saving all images and post processing, which have an associated storage, connectivity, and compute overhead.

Despite analysing 10^6 data points, this is still only a snapshot of the overarching dataset as this work only considered data collected at midday. This work has also been ruthless in omitting data points, using a relatively high confidence threshold for detection. The FCCN itself acts as a marginal surfing wave quality filter, as it was trained using images taken during relatively clean conditions. If more detections during inclement conditions were included, a correlation to local wind speed would be a likely starting point for further investigation.

5. Summary

The ongoing monitoring and establishment of natural baselines of coastal resources are imperative to sustainable management. This work presents the results of monitoring the surfing wave quality parameter of peel angle using a novel technique that used a remote cameras system and machine learning. The camera system provides the ability to consistently monitor surfing wave quality, instead of relying on a snapshot from aerial and satellite imagery. The result is an abundance of data that requires detailed analysis.

While no significant correlations to environmental variables have been identified. Relationships between peel angle and tide, wave height and period, and their spatial variability have been identified.

In terms of quantitative and meaningful surfing wave quality monitoring, this is the first application of this technology combination. This approach can be readily replicated at other sites to aid in the sustainable management of surfing resources and could be used in real-time surfing wave quality reporting.

6. References

[1] Atkin, 2010. The Impact of an ASR on Breaking Wave Conditions at Boscombe, UK. Thesis: University of Southampton, UK.

[2] Atkin, E. A., Mead, S. T., Bryan, K., Hume, T. and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. Proc. of the 24th Australasian Coasts and Ports Conf., Cairns, Aus., 21-23 June 2017.

[3] Atkin, E., Bryan, K., Hume, T., Mead, S. T., and Waiti, J., 2019a. Management Guidelines for Surfing Resources. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research.

[4] Atkin, E., Bryan, K., Mead, S. T., Hume, T., and Waiti, J., 2019b. Management Guidelines for Surfing Resources. Proc. of the 24th Australasian Coasts and Ports Conf., Hobart, Australia, 10-13 September 2019.

[5] Atkin, E.A., Mead, S.T., O'Connell-Milne, S. and Davies-Campbell, J. 2021a. Surf Break of Regional Significance: Southland. eCoast technical report prepared for Environment Southland.

[6] Atkin, E.A., McIntosh, R. and Davies-Campbell, J. 2021b. Deep learning object detection application to surfing wave quality. Manuscript in preparation.

[7] Bryan, K.R..; Davies-Campbell, J.; Hume, T.M., and Gallop, S.L., 2019. The influence of sand bar morphology on surfing amenity at New Zealand beach breaks. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. J Coastal Res., SI No. 87, p. 44-54. Coconut Creek (Florida).

[8] Dally, W.R., 2001. The Maximum Speed of Surfers, In: Black, K.P. (ed.), Natural and Artificial Reefs for Surfing and Coastal Protection, J Coastal Res., SI No. 29, p. 33-40.

[9] Egbert, G.D. and Erofeeva, S.Y., 2002. Efficient inverse modeling of barotropic ocean tides. J Atmos. and Oceanic Tech. 19, 2, pp. 183-204.

[10] Gallop, S.L.; Bryan, K.R., and Coco, G., 2009. Video observations of rip currents on an embayed beach. J°Coastal Res., SI No. 56, 49-53.

[11] Hersbach, H, Bell, B, Berrisford, P, et al. The ERA5 global reanalysis. Q J R Meteorol Soc. 2020; 146: 1999–2049.

[12] Holman, R.A and Stanley, J., 2007. The history and technical capabilities of Argus. Coast Eng, 54, 6, p. 477–491.

[13] Hutt, J. A., Black, K. P. and Mead, S. T., 2001. Classification of Surf Breaks in Relation to Surfing Skill. In: Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, J Coastal R, SI No. 29, p. 66-81.

[14] Jocher et al., 2020. Ultralytics/yolov5 Version v3.0. DOI: 10.5281/zenodo.3983579

[15] McIntosh, R., Atkin, E.A. and Davies-Campbell, J. Development of an Automated Peel Angle Detection System for the Manu Bay Surf Break. New Zealand Coastal Society. New Zealand Coastal Society Conference, Gisborne, 2018.

[16] Mead, S.T., 2000. Incorporating high-quality surfing breaks into multi-purpose offshore reefs. Hamilton, New Zealand: University of Waikato, Ph.D. dissertation.

[17] Mead, S.T. and Black, K.P., 2001a. Field Studies Leading to the Bathymetric Classification of World-Class Surfing Breaks. In: Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, J Coastal R, SI No. 29, pp. 5-20.

[18] Mead, S.T. and Black, K.P., 2001b. Functional Component Configurations Controlling Surfing Wave Quality at World-Class Surfing Breaks. In: Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, J Coastal R, SI No. 29, pp. 21-32.

[19] Mead, S.T. and Black, K.P., 2001c. Predicting the Breaking Intensity of Surfing waves. In: Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, J Coastal R, SI No. 29, pp. 51-65.

[20] Moores, A., 2001. Using Video Images to Quantify Wave Sections and Surfer Parameters. Hamilton, New Zealand: The University of Waikato, Masters Thesis, 143p.Scarfe, 2002

[21] Rodriguez-Padilla, I., Castelle, B., Marieu, V. and Morichon, D., 2020. A Simple and Efficient Image Stabilization Method for Coastal Monitoring Video Systems. Remote Sensing, 12, 70.

[22] Scarfe, B., 2008. Oceanographic Considerations for the Management and Protection of Surfing Breaks. PhD thesis, University of Waikato, New Zealand. 307p + appendices.

[23] Walker, J.R., Palmer, R.Q. and Kukea, J.K., 1972. Recreational Surfing on Hawaiian Reefs. Proceedings of the 13th Coastal Engineering Conference.

[24] Walker, J.R., 1974, Recreational Surf Parameters, Honolulu, Hawaii, USA: University of Hawaii, Look Laboratory Report No. 30, 311p.

10 Discussion

This chapter summarises each of the published works and shows how they link together to form a coherent body of work. Where relevant, each section considers the context of previous and contemporary work, shortcomings of the approach, steps for future research and the contribution made. This is followed by sections on how the work addresses the research questions: What critical components need to be considered for sustainable surf break management? What are the roles and relationships of actors involved in surf break management, including, user groups and stakeholders, experts and consenting authorities? How can the key geophysical characteristics and processes that contribute to surf break functionality be better identified and understood? Following the outcomes of this research, in this chapter, research questions 1 and 2 are reworded with “surfing resource” replacing “surf break”. Finally, a conclusion that highlights the overall contribution of the complete works and summarises the key learnings.

10.1 Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance

Chapter 2 introduces the overarching research project and a summary of the initial characterisation of 7 study sites considered throughout this research. This stage of the research was underpinned by literature reviews and stakeholder engagement with qualitative surveys. Surveys and engagement were conducted as part of the Ministry for Business, Innovation and Employment (MBIE) Targeted Research Fund project, and were made available for analysis and synthesis in this thesis. This research piece, and the technical report (Appendix D), formed the foundation for the development of the Guidelines.

Despite considering only 7 breaks, no stakeholder engagement of this nature, which included technical, social and cultural aspects across multiple breaks, had been undertaken to date. The collation of existing local knowledge using annotatable aerial images was an effective tool that also initiated discussion and inspired reflection, as was having multiple experienced researchers available to engage with participants. The number of participants at the workshops was limited in some cases, although there were no reticent attendees when it came to sharing, which was a testament to both the approach to engagement and the willingness of the surfing public to contribute to the project’s aims and objectives. Increasing the number of participants is certainly something that would have improved this component of the research. Low participation in workshops was countered with the online survey programme. The online surveys were informative but were not analysed in a quantitative or statistical manner, such as the use of the demographic data collected by the project.

The study sites were selected (see Chapter 3 and Appendix D) using a scoring system that included: access, existing infrastructure, surf break sensitivity; existing or potential threats, usage, dependent population, the assumed effectiveness of the study methods and the presence of Surf Life Saving New Zealand. Expanding on the scoring categories to include cultural components may have had an impact on which study sites were selected, and therefore the stakeholder engagement. The scoring of these categories was undertaken by this author, based on knowledge of the sites, research, enquiries and literature review. An alternative approach would have been to undertake a national survey to determine the importance of study sites or simply provide independent scoring.

The key perceived and/or potential threats of development on surfing resources is well documented. Water quality was highlighted as a major anthropogenic threat to surfing resources in ANZ, which is consistent with findings elsewhere; and justifies its inclusion in the Guidelines (see Chapter 3 of Appendix A) of activities in the hinterland, catchment and waterways. Scott and Rodgers (2018) found 70.8% of surfers (in the Gulf of Maine) believe water pollution to be a threat. Ratten (2018) reports that water quality in the World Surfing Reserve at Santa Cruz (California, USA) affects many stakeholders. Through modelling of a watershed in Peniche (Portugal), Marteleira *et al.* (2018) highlight the health risk posed to surfers with high concentrations of total faecal coliform associated with pig farms reaching the coast and surfing resources. Arnold *et al.* (2017), Soller *et al.*, (2017) and Steele *et al.*, (2018) all report on the health risk posed to surfers, who, when compared to the general coastal environment user, are exposed to the elements for prolonged periods. This can also be when other users completely refrain from being in coastal waters, such as in winter months and/or rainy seasons (Soller *et al.*, 2017).

This work highlights the importance of stakeholder engagement and the inclusion of traditional custodians. The Guidelines include a chapter with resources to aid in engagement with Māori. Meaningful and respectful engagement combined with the workshop approach allows the involvement of local stakeholders.

As part of the overarching research project, multiple RipCurl GPS watches were distributed during stakeholder engagement which allowed the research team to identify suitable users. GPS data collected with the watches was used in the characterisation of surf breaks (Borrero *et al.*, 2019; Hume *et al.*, 2019). While the use of surfer-GPS is not novel, it was the first use of the RipCurl product in surf break characterisation and the way the watch was distributed aligns with a citizen science approach. Replicating the application of the RipCurl GPS, particularly at a specific surf break with known users, is cost prohibitive, and a low-cost alternative to collect the same quality of data would open up a research stream to the benefit of surf science and engineering, tourism, management, conservation and other research disciplines.

10.2 Management Guidelines for Surfing Resources

The term '*surfing resource*' was used briefly by Ponting (2006) in regard to surf tourism, and similarly by Lazarow (2007) in describing the economic, social and cultural importance of surfing amenity[6]. More extensive use of '*surfing resource'* is by Corne (2009) when describing the potential impacts of activities in the coastal zone on surfing. Since then, the use of the term surfing resource has gained popularity in time, especially in association with research that includes elements of tourism. Surfing resource is infrequently defined, despite its almost explicit use in some work (e.g., ASBPA, 2011). Corne (2009), SAS (2009), Ball (2015), Blum (2015) and Blum and Orbach (2021) all provide descriptions for a surfing resource which they determine relevant for their particular work. All descriptions are entirely geophysical, making note of the waves, bathymetry and, in some cases, wind, and are synonymous with the physical feature description of a surf break provided in the glossary of the NZCPS.

Policy 16 acknowledges the importance of the physical component but also identifies the aesthetic and cultural aspects as important to users of those environments. Fundamental attributes beyond the physical components that make up a surf resource include rarity, frequency, uniqueness, naturalness, wilderness value, amenity value, level of use, economic value, historic, heritage and cultural associations, and educational value (Orchard *et al.*, 2019). This research determined that a surfing resource is the combination of physical processes (associated with the surf break), sense, feeling, and experience that make it a natural and social resource. It is therefore important to recognise the requirement to manage the resource holistically and not to treat aspects of this resource in isolation.

Earlier references to 'surfing resource management' are limited to Martin (2010) and Martin (2012) who considered social, economic, and environmental components of surf breaks in Thailand. Martin (2012) does not go as far as to explicitly define a surfing resource but maintains the perspective that a surfing resource is more than the physical components. The use of *surfing resource management* has proliferated in conjunction with this research project.

Previous work regarding management refers to the *Sustainable Management of Surfing Breaks* (Scarfe, 2008; Scarfe *et al.*, 2009a), *Surf Break Co-Management* (Edwards, 2013),

[6] 'Surfing resource' is used once by Zane (1992), however the usage is out of context.

Planning Approaches for the Management of Surf Breaks (Skellern *et al.*, 2013), *Surf Breaks and Implications for Management* (Peryman and Orchard, 2013), *Comprehensive Surf Break Protection* (Reiblich, 2013), *Surf Break Conservation and Management* (Arroyo *et al.*, 2019), and *Protecting California Surf Breaks* (Blum and Orbach, 2021). The consistency between these management research pieces is the reference to 'surf break' or 'surfing break'.

Public and stakeholder engagement provided an essential foundation for the Guidelines. Anthropogenic changes affecting the Whangamata Bar and the associated issues, provide a good example of poor stakeholder engagement, the result being protests opposing the marina development leading to a review of the consent process (Thomberson, 2012). The monitoring and level of analysis for the Whangamata Bar consent are questionable, despite the consent specifying that an appropriately qualified and experienced person was to develop a plan detailing the procedure for monitoring and to ascertain if the dredging and construction have had any long-term adverse effects. Atkin *et al.* (2013), which includes analysis of bathymetry and peel angles from numerical modelling, provides a quantitative surf break characterisation and is much more detailed and informative in its assessment of impacts than was provided as part of the resource consent.

Having a tailored management plan for an individual site (e.g., Surf Coast Shire, 2015) means the documentation can be area specific, less generic, more focused, and targeted. The Guidelines provide a reference point for the development of local management plans. Arroyo *et al.* (2019) combined the management frameworks of Social-Ecological System (SES) and Driving-Forces-Pressure-State-Impact-Response (DPSIR) to identify issues relating to a surfing resource. Elements of this approach would lend themselves very readily to the characterisation of surfing resources and should be considered in future revisions.

A shortcoming of the Guidelines is that they do not consider the potential impacts of Climate Change and Sea Level Rise (SLR). This subject matter is not widely discussed in surfing research literature. The California Coastal Commission's guidance (CCC, 2018) acknowledges that surf breaks are vulnerable to the effects of SLR and have promoted research to better understand SLR impacts on surfing (Atkin *et al.*, 2020; Chapter 4). Reineman *et al.* (2017) indicate that surf breaks in California are threatened by SLR. Atkin and Mead (2017) consider that reef breaks are particularly susceptible to the effects of SLR, whereas beach breaks can, theoretically, respond to changes in sea level, and that there is potential for new surf breaks to form. Clifton *et al.*, (2013) assumed that the quality and operation of key reef-based surf breaks in the Surf Coast Shire (Aus. e.g., Bells Beach) would be compromised by SLR. Atkin and Mead (2017) attributed a lack of a broad study on surfing wave quality and its relationship to SLR, to a lack of sufficient surfing wave quality data.

The threats and risk assessment presented in Chapter 3 are based on an assessment of a surf break's sensitivity, which is a function of the geomorphological composition. The basis of the model is that the more the morphology is dependent on sediment transport processes, the higher the sensitivity rating. The Guidelines describe hypersensitive surf breaks where the mobility of the sandy substrate is highly dependent on local coastal processes and recommend site-specific studies to determine sediment transport regimes and their relation to surfing wave quality. As previously stated, reef breaks are more sensitive to the effects of SLR than surf breaks with mobile substrates. It is recommended that a separate risk assessment is utilised when considering the effects of SLR and that a starting point is to consider an inverted version of the sensitivity rating presented in this work.

A challenging component of surfing resource management is the demand associated with surf tourism and increasing participation numbers, which have been associated with the threats of overcrowding (Borne and Ponting, 2017). Mitigation in the guidance recommends improving facilities and introducing signage to educate about surfing etiquette. Martin and Assenov (2014) presented a Surf Resource Sustainability Index for assessing the sustainability of surf tourism sites and considered the implications of particular societal, economic, environmental and governance scenarios. Martin and Assenov (2014) do not provide any specific management guidance or solutions; with regard to management under their Governance Index, the action specified is to '*Identify the existence of guidelines*'.

The Guidelines address the entire Environmental Impact Assessment (EIA) checklist of Scarfe *et al* (2009a). Detailed characterisation of a surf break is an involved process and, in some cases, the processes that act to maintain a surf break are very complex. The involvement of local knowledge holders in detailed characterisation cannot be understated. The early identification of certain bathymetric features, whether they be large precondition components or submeter pinnacles offering distinct sections in wave breaking (Mead and Black 2001b), is critical to how the rest of detailed characterisation is undertaken, from the types of questions asked of stakeholders to the resolution of a hydrographic survey or the numerical modelling of waves.

In 2020, the content and purpose of the Management Guidelines for Surfing Resources have been given support by ANZ's Department of Conservation (K Bell 2020, personal communication, 30 January). The Guidelines could however be improved by expanding the content to include extensions of the social and cultural aspects and incorporate economic considerations, including surf tourism. The Guidelines were developed with reference to previously published works that deal with similar topics. However, the Guidelines were not developed within the context of the theoretical background of developing guidance, co-design or collaborative decision-making. The first step in developing a next iteration/version of the

Guidelines will be to assess them in the context other relevant published works. The latest, relevant research will also need to be considered, with a broader range of experts being involved to ensure all elements of the surfing resource (not just the surf break) are being considered equally. A valuable exercise will be to determine the retrospective usage and application of the Guidelines on case studies, and provide them as examples moving forward.

10.3 Applicability of Management Guidelines for Surfing Resources in California

Chapter 5 considers the utility of the Guidelines outside of ANZ. The paper provides a concise description of the governance setting in ANZ and the Guidelines, unpackages national, state, and local laws/policies of California, and discusses the linkages with the Guidelines. While the Guidelines include management considerations specific to ANZ's cultural and legal frameworks, much of the content is relevant to surfing resource management worldwide. Chapter 4 highlights the feasibility of generalising the Guidelines. The benefits of developing generic guidelines are to provide an interpretable resource for countries that do not have the resources to develop country-specific guidance. The value of a set of generic guidelines is exemplified in Martin and Assenov (2014) where action under the Governance Index is to identify the existence of guidelines. The development of a generic set of guidance for sustainable surfing resource management would be a large undertaking involving a global set of independent experts. The global guidelines would need to be stress tested in different environmental settings. The Guidelines presented in this body of work have not only provide a reference point to critically analyse management practice outside of ANZ, but provide a great foundation for the development of generic, globally applicable guidance.

Martin and O'Brien (2017) discuss 'surf system boundaries' and consider surfing reserves (Farmer and Short, 2007) and Marine Protected Areas (MPAs) as mechanisms of delineation. This paper noted the utility of MPAs in coastal California and the requirement for delineation. In the Guidelines, delineation falls under identification, which would be the first proactive step for a holistic approach to surfing resource management in California.

California has two World Surfing Reserves (WSR), hosts Mavericks, one of the world's premier big wave surfing locations, has some of the largest and most attended surfing competitions, has almost a full range of geomorphological surf break types, including those that are considered world-class, and, at the time of writing, hosts the World Championship Tour (WCT) finals event at Trestles in Orange County. While California's surf breaks are internationally famous, this status offers no guarantee of sustainable management. The status of certain surf breaks will no doubt ensure any activities that may impact the resource will be considered carefully, but what about the less reputable surf breaks? Identification of surfing resources with authorities is considered a key step in ANZ, and this is no different in California, and likely worldwide.

One issue the identification process presents, which surfers consistently raise and/or encounter is the exposure of lesser-known surf breaks, secret spots, Surf Breaks of Local Significance (SBLS; Atkin, 2017; Atkin and Mead, 2017), or Locally Sensitive Breaks (LSBs; Orchard, 2017b). For those wishing to protect the current values associated with the surfing resources, failing to identify a secret spot could result in detrimental activities and associated impacts, and so poses a moral conundrum for user groups. Orchard *et al* (2019; Appendix B) discuss management options which include the use of a hidden inventory that would only be called upon in the event of potential impacts and the use of more discrete methods for delineation such as a Known Surfing Coastline (KSC), which identifies sections of coast where surfing is known to be undertaken and/or possible. These approaches are yet to be fully tested, however, the KSCs of Atkin (2017) did provide supporting documentation in a consent hearing for aquaculture development in Mercury Bay (Mead, 2019), and would have allowed the applicant to undertake a comprehensive characterisation of the surfing resources had the KSC documentation been identified earlier on in the process.

10.4 A Comparison of Methods for Defining a Surf Break's Swell Corridor

The concept behind the construction of swell corridors is to provide an interpretable planning tool for authorities, proponents and opponents. Martin and O'Brien (2017) reviewed different approaches to delineating a surfing resource, however, it does not specify delineation beyond encompassing the socioeconomic and cultural setting combined with the geophysical components of the surf break. The paper presented in Chapter 5 uses the Surf Break Area (SBA) concept (after Atkin *et al.*, 2015; Atkin and Mead, 2017). SBAs were established when constructing swell corridors, as a delineation for interpretation of modelling results was required. SBAs allowed multiple surf breaks that are in close proximity, and that shared similar requirements for incident wave conditions to be grouped. Atkin and Mead (2017) noted that the wider area of a surf break holds economic, social and amenity value. The establishment of SBAs used historical aerial photographs, noting any apparent breaking wave patterns, existing bathymetric data, published information and knowledge gained from local consultation.

The recommended method, which leverages long-term, hindcasted, two-dimensional wave spectra and winds, was used to define swell corridors in the Southland Region (Atkin *et al.*, 2021). In the Waikato (Atkin and Mead, 2017) and Wellington (Atkin *et al.*, 2015), validated idealised conditions were used to define the footprint, and percentage occurrence thresholds defined the swell corridor and buffer zone interface. In Southland (Atkin *et al.*, 2021), all filtered incident waves were used to define the footprint of the swell corridor, but a 1 km buffer zone around each swell corridor was included. The rationale for the buffer zone included, in no particular order:

- Giving effect to the precautionary approach set out within Policy 3 of the New Zealand Coastal Policy Statement (NZCPS).
- The numerical model was not calibrated to site-specific data and numerical modelling is always limited by some form of spatial resolution.
- Any developments proximal to an established SBA have the potential to affect wave conditions within that SBA (e.g., a seawall adjacent to, but not inside, an SBA may cause wave reflections and alterations to breaking wave properties within the SBA).
- Supporting the objectives of Policy 16 of the NZCPS in 'avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks'.
- Gives effect to Policies 13 and 15 of the NZCPS that require the preservation of natural character and the protection of natural features.

One element that Atkin *et al.* (2015), Atkin and Mead (2017) and Atkin and Greer (2019) failed to discuss is the dependence each along-crest section of a wave has on its adjacent sections. The swell corridor methods leverage discrete traces of incident waves; however, the section of wave each trace represents is dependent on the adjacent parts of the wave crest in its propagation through the ocean, across the continental shelf and into nearshore waters. A reasonable assumption is that the sheer volume of traces, by using a long-term hindcast, would account for any potential dependence within the bulk of the designated swell corridor. However, the fringe conditions, those that stretch the limits of the corridor, would not, and this is an additional reason for the inclusion of a buffer zone. The question remains as to whether the width of the buffer zone is appropriate, and the answer is likely to be a function of location, offshore bathymetry and wave climate.

Sensitivity testing of the settings of the wave model, which are very wide and varied (The SWAN Team, 2020), is an exercise that was not undertaken as part of this work. Published work has shown the wave model to be accurate and robust. However, changes to model settings that are often used to calibrate the model to collected environmental data (e.g., wave height, period and direction) may result in changes to the wave field, Relative Percentage

Activity and the footprint of the swell corridor, when compared to an uncalibrated version, or simply those with different model settings. This leads on to the question, what if a different wave model were employed? For site specific cases, like those being the focus of a consenting processes, calibration of the wave model should be an imperative part of surf break characterisation. In addition, an understanding of the restoring forces of disturbed waves and the scales upon which they operate, and the effect this has on surfing wave quality and resource use, needs to be investigated.

10.5 Investigations of Offshore Wave Preconditioning

Chapter 5 provides the first published compilation of the geometry of natural preconditioning features, and uses the data to inform the generation of a range of bathymetric configurations, that are tested with monochromatic wave conditions to understand the role that geometry plays in preconditioning. After Mead *et al*. (2003), this work further evidenced the very broad range in scale of preconditioning components, and through analysis of the geometry showed that the components are found in all shapes and sizes. It is noted however, that the sample set used in this work is limited. If the database of preconditioning features was expanded there is the potential for the results of this work to be different, and there may be further relevant findings from a coastal management perspective.

The research conceived the notion of a spectrum of preconditioners, from disruptive to focusing. Disruptive preconditioners create wave interference patterns in the lee of the structure, whereas focus preconditioners create a notable peak with less widespread disruption and are synonymous with the focus component of Mead and Black (2001a, 2001b). The two types of preconditioners represent the ends of a disruptive-focus spectrum, where the size of the preconditioning feature relative to incident wave height was identified as a key variable in the role a structure plays. More work is required to better understand this relationship between structure geometry and incident wave conditions, especially in conjunction with wave period.

This research established a platform for further investigation, including: exploring the relationship between incident wave conditions and feature scale (including lower limits), and whether empirical models can be established; the isolation and decomposition of preconditioning features, analogous with the functional component work of Mead and Black (2001b); the inclusion of morphological response to offshore preconditioning features (Mead and Atkin, 2022); and the role of 'repairing' or restoring factors. The latter will have implications on activities such as aquaculture and renewable energies that can be undertaken within or adjacent to a surf break's swell corridor.

A better understanding of the role of preconditioning structures will be useful in both the design of anthropogenic structures, or Multi-Purpose Reefs (MPRs), that can provide resilience through beach widening and/or salient formation, and improved amenity value through surfing and habitat enhancement. While analogous with established MPRs that break waves, a preconditioning MPR would very likely have reduced design constraints and construction overheads. This is countered by a likely requirement for increased volumes as a function of the structure being in deep water. The habitat enhancement benefits would also be better realised, with structures in the surf zone or associated with wave breaking not providing the safest environment for non-surfing activities such as fishing (boat, spear) or recreational diving.

This work highlighted the role that offshore preconditioning plays in surfing wave quality, and the scale at which it operates, which are both important factors for the management of surfing resources and, in particular, the area offshore occupied by the swell corridor.

10.6 Deep Learning Object Detection Application to Surfing Wave Quality & Machine-learned Peel Angles for Surfing Wave Quality Monitoring

This section considers Chapter 7 and Chapter 8 together as the capability established in Chapter 7 is applied in Chapter 8. Peel angle is arguably the most important of the surfing wave quality parameters. A surf break may be characterised by waves that break in a spilling manner or be famous for extreme vortex ratios and collapsing sections, or known as a short, sharp and shallow rocky slab, or for long, mechanical waves that exhaust users' energy in a single ride. In each and any scenario, if the wave does not peel at a suitable rate then the breaking wave is not useful for performance surfing.

To address the requirement for establishing a quantitative baseline, previous work has considered monitoring peel angle with remote camera systems (Atkin 2010; Davies-Campbell 2018; McIntosh *et al.* 2018; Scarfe, 1999). The methods required considerable manual effort or cumbersome computations. The first step in developing an automated approach is described in Chapter 7, where the Convolutional Neural Network (CNN) is trained to identify the two components imperative to calculating peel angle: the instantaneous breaking part of the wave, or pocket, and the orientation of the wave crest.

There is room for improvement, with an evaluated model accuracy of less than 80%, but a range of model parameters were tested and ultimately the consistency in the annotation of images (Karimi *et al.* 2020) and the volume of annotated images (Jocher *et al.*, 2020) are key components that should be considered in developing the model, where more instances of the object to be detected are required. The approach also relied on the assumption that the instantaneous point of breaking is always higher in the image than a point along the associated wave crest, so that the crest orientation could be defined, a good assumption based on the training set, but an assumption, nonetheless. Computer vision and object detection is advancing very quickly, and such assumptions can likely be omitted in the near future, such as the use of a bounding box which includes rotation.

The research described in Chapter 8 establishes relationships with environmental parameters and was able to corroborate and expand on our understanding of previous work on peel angles at Manu Bay. Despite this, more research is still required to determine a standardised method for interpreting the vast number of data points that can be collated using these methods.

Despite these shortcomings, a novel technique has been developed to automatedly monitor surfing wave quality using a remote camera system and machine learning, a first for this technology combination. While the Neural Network approach is based on real, accurately annotated data, and the methods of oblique image georectification are well established, a comparison with manual peel angle measurements using nadir imagery (such as that from a drone) would be valuable for validation. The data could be used in conjunction with phase-resolving models of wave propagation and breaking, which could then in turn be used to either better understand surf break dynamics or evaluate any proposed coastal activities that may impact the resource.

10.7 What Critical Components Need to Be Considered for Sustainable Surfing Resource Management?

Chapters 2, 3, and 4, along with the Management Guidelines for Surfing Resources in their entirety, present sets of steps for both authorities and those wishing to undertake activities within the coastal environment. These steps were determined through extensive engagement with user groups, stakeholders, scientific experts, planners, managers, regional authorities, government departments and conservation groups, combined with experts in the field with extensive experience and exposure to surf break management issues, and the contents of previously published works. A key outcome of this work has been the acknowledgement and definition of a surfing resource which in its self-addresses Research Question 1. A necessary exercise moving forward will be to determine the robustness of this definition and its applicability outside of ANZ.

Identification of surfing resources is the first step for both authorities and those wishing to undertake activities within the coastal environment. Without the identification of the surfing resources, management tends towards being reactive, which opens up the potential for hurried or ill-informed assessments. Identification cultivates the opportunity for baseline data collection to be established. While baseline data collection is a component of most Environmental Impact Assessments, surf breaks are very complex and dynamic components of the coastal landscape, that are often little understood. In ANZ, at least, the NZCPS promotes both a precautionary approach (Policy 3) and the identification of natural features with a note to dynamic components (Policies 13 and 15).

An assertion made during the length of the research project, and one that applies well beyond surfing resources, is that we cannot manage that which we do not understand. A precautionary approach is stipulated in the NZCPS where effects are considered uncertain, unknown, or little understood, but this should not detract from trying to understand. An understanding starts with knowing what is there. In terms of technical requirements, such as complex numerical modelling, identification is a low-overhead exercise. There is a wealth of existing resources in ANZ and worldwide for identifying the bulk of surfing resources and consultation with local user groups can provide an extra layer of detail and/or validate third party sources. Identification is not, however, without issues, most notably the historical tendency for surfers to withhold information about certain surfing locations – aka secret spots. This is discussed in Atkin (2017) and Orchard *et al.* (2019). Ultimately, a local community should decide on the scope for the identification of natural resources. In some cases, being secret is essentially an attribute value associated with significance (Orchard *et al.*, 2019). The compromise is that authorities and/or resource users and consent applicants are not aware of the resource, leaving it exposed to impacts; which could range from access issues to destruction.

Part of identification is characterisation and, in retrospect, the step name should include the latter. Characterisation starts to fill in the void of a lack of understanding and should include determination of the actual surfing area including access points, common and colloquial naming, parts or sections of the resource, the types of waves being surfed, and information regarding the drivers of change, especially concerning surfing wave quality. The characterisation data is used to establish and map a SBA. The SBA may host a single surf break or multiple surf breaks.

The final components of identification are to compile the information in a database and to categorise the significance of surfing resources (Orchard *et al.*, 2019). These components are not considered critical but would aid in day-to-day management. Determining the significance of each SBA is useful if an authority uses a stratified approach to resource management.

The role of local expert knowledge holders is imperative in the identification and characterisation of surfing resources. However, this information stream should be evaluated by an expert in the relevant field (e.g., surf science, cultural, planning), or assumptions could end up influencing decision making.

The Guidelines for Resource Users and Consent Applicants extends the identification components and includes detailed characterisation, with the inclusion of onsite data collection and bathymetry, sediment transport regimes (if any), the construction of swell corridors, calibrated numerical modelling of wave breaking characteristics and assessments of surfing wave quality, culminating in the determination of formation and maintenance mechanisms.

Shand *et al.* (2019) modified the risk assessment methodology from the Guidelines and applied it to their design of a rock revetment at Mangamaunu, a Surf Break of National Significance in ANZ. While the proposal to construct the rock revetment with a reclamation was eventually rescinded following a judicial review of the emergency consenting powers and settled through mediation (Rennie, 2018), Shand *et al.*'s (2019) assessment criteria lacked surf science-specific reference. The risk assessment recommended as part of the Guidelines incorporates information about the geomorphological composition of a surf break to develop a sensitivity rating. Shand *et al.*'s (2019) approach to the consequence of activities, considered surf breaks of 'Low Quality' and 'High Quality' without providing any methodology for defining their quality categories. Whereas the Guidelines include surfing resource use definitions for consequence, and do not differentiate between quality; consequence should not be a function of what is often found to be subjective. Changes in water level were considered in the risk assessment of Shand *et al* (2019), but not as part of the methodology. SLR will likely need to be included in some risk assessments and future revisions of the Guidelines will need to incorporate the latest understanding of CC/SLR effects on surfing resources and methods for evaluating them. This may present a significant challenge, as evaluating CC/SLR impacts on surfing resources requires consideration for phenomena that are direct, such as wind and wave climate and water level changes, and indirect, such as precipitation rates. A key consideration for construction within the CMA is how a structure may interact with coastal processes under different SLR scenarios and how this may impact surfing wave quality.

The inclusion of surfing resources in policy and plans prevents ambiguity. If proponents have undertaken their procedure comprehensively then they will understand their obligations and opposition from stakeholders should be reduced. Monitoring is a proactive step that facilitates the establishment of a baseline dataset. Except for integrating surfing resources in policy and plans, monitoring data will improve the outcome of all the other key components of implementable surfing resource management, and alongside identification, should be considered more critically.

10.8 What Are the Roles and Relationships of Actors Involved in Surfing Resource Management, Including User Groups and Stakeholders, Experts and Consenting Authorities?

In ANZ, consenting authorities, under the NZCPS, are obligated to undertake the identification of surfing resources. Authorities in ANZ, and beyond, should at least familiarise themselves with the management tools available, such as a database of delineated SBAs and swell corridors. In ANZ, the authorities will specify whether a stratified significance approach to resource management will be implemented. Recognition of the top tier, Surf Breaks of National Significance (SBNS), is mandatory. Beyond SBNS, and to date, surf breaks of regional and local significance, KSCs and 'nursery breaks' (Department of Conservation, 2009), have been considered within planning, but there is little region-to-region consistency (Orchard et el., 2019; Appendix B). Some stakeholders disagree with the stratified approach, their view being that less protection is offered to surf breaks in a lower significance tier. However, the approach is favoured by some authorities as it provides a structure for the allocation of resources. The management strategy should be considered on a case-by-case basis and identification and consultation with an expert may be required before settling on a strategy. Some regions may have very few surfing resources, allowing for homogeneity in significance.

The fate of secret spots should be left to the major local user groups. The decision-making process for this within stakeholder engagement is not established and needs some consideration. This again highlights the importance of local community participation in surfing resource management. Local experts and traditional knowledge holder input are integral to almost every one of the steps outlined in the Guidelines. Stakeholders have also made authorities aware of issues and the potential for impacts from activities in the CMA and Coastal Environment. In ANZ, user groups have changed the legislative landscape, largely because the implementation of the NZCPS is mandatory under the Resource Management Act (1991). As experienced in ANZ, policy reform provides the most likely opportunity for user groups and stakeholders to integrate surfing resource management expressions into policy. A community-focused approach will meet the needs of user groups and stakeholders and will continue to shape how surfing resource management is implemented.

A key role of experts, that is those with proficiency in surf science, coastal processes, policy and planning, is twofold: to interpret information garnered from local user groups and stakeholders; experts will likely have to determine or filter between real and perceived threats, processes and phenomena; and, to extract critical information from those that do not feel it is relevant, or are less willing to share (whether that be a general reluctance, confidence, availability etc.). This research leveraged multiple experts with a broad demographic and combined multiple forums or platforms for information sharing. An assumption made, based on a lack of negative feedback and the research program achieved its aims and objectives, is that the approach was well-received and considered to work effectively. A review and critique of the approaches for engaging with stakeholder's with a focus on surfing resources will be a valuable future exercise.

In a broad summary of applied surfing resource management, authorities determine the methodology and strategy (informed by experts), users groups and stakeholders provide local expertise and community requirements, and experts moderate, provide a facts-based approach (which may be technical) and ensure strategies are in line with the legislative setting. This work has included the development of tools for assessing surf break functionality and establishing environmental baselines that feed into the Guidelines. A challenge that surfing resource management faces is how these tools, which are underpinned by technical expertise, become accessible to decision makers. Without a similar level of technical expertise inhouse, authorities will likely be reliant on external consultants until objective, user friendly frameworks can be implemented. The swell corridors work provides a first step in this direction with a heuristic spatial planning approach.

10.9 How Can Key Geophysical Characteristics and Processes That Contribute to Surf Break Functionality Be Better Identified and Understood?

There is a range of components and processes, that are not all necessarily oceanographic, that contribute to the maintenance and surfability of a surf break. A commonly used term in integrated coastal zone management is 'Ridge to Reef', which acknowledges that there is an interdependency between various environmental settings, but they are not all necessarily associated with the coast. This is certainly true for surfing resources, but there is a requirement to broaden the range of environmental settings offshore, with 'Ridge to Continental Shelf' being more appropriate. Ridge acknowledges that processes and activities in the hinterland can impact the coast. In surfing terms, examples include sediment load and water quality impacting usage; and, riverine and/or tidal flow influencing ebb tidal delta dynamics, with knock-on effects to bathymetric configurations and surfing wave quality.

The location of naturally occurring functional bathymetric components (Mead, 2000; Mead and Black 2001a; 2001b) can range from the inside of estuaries, rivers (even lakes) or inlets and embayments, to extensive fringing and outer reefs, to isolated atolls and seamounts; although the bulk of components are found in the generalised coastal zone. As discussed in the introduction and Glossary of the NZCPS, the swell corridor, the area offshore, is considered to be an integral component of a surf break. It is this offshore area and the processes that occur within it that have been the focus of this work to answer, in part, the third research question.

Constructing the swell corridor for a surf break (Atkin *et al.*, 2015; 2021; Atkin and Greer, 2019; Atkin and Mead 2017) provides the geospatial tool to delineate the important area offshore of the surf break. The approach presented in this thesis (Atkin and Greer, 2019; Chapter 6) leverages hindcast wave conditions. Examination of collocated simulated wave conditions, the bathymetric grid and constructed swell corridor permits the user to discern any functional components. Simulations with and without certain seabed features, with various incident wave conditions, can be undertaken to determine the particular importance of each seabed feature. This work has taken steps to better understand the often very dynamic role of features within a swell corridor. Chapter 7 (Atkin *et al.*, 2019) suggests a spectrum of preconditioning (after Mead, 2000), from disruptive to focusing. The role these preconditioning features play in shoreline response and sediment transport, balanced against surfing wave quality, is a current stream of investigation (Mead and Atkin, 2022).

Inside an SBA are the more thoroughly researched functional components of Mead (2000; Mead and Black, 2001a; 2001b), who used numerical models to identify common configurations from a set of measured surf break bathymetries at high-quality surf breaks in ANZ and internationally. Functional components can be identified through the examination of bathymetry, but how they contribute to the way wave breaking is best explored using phase-resolving models, or computational fluid dynamics. From a day-to-day management perspective, gaining an understanding of functional components within a SBA would be a very site-specific, involved process, and likely a component of detailed characterisation undertaken by a proponent. The answer to Research Question 4 proposes an approach that integrates the monitoring of functional components to discern if and how they change over time.

The persistence in the usage of a surfing resource is dependent on a range of things, however, the attribute values of wave quality and/or access are of the utmost importance. Related to surfing wave quality is incident wave conditions, including wave height, period and direction. The wave conditions are important as they can be considered when looking at the drivers of surfing wave quality change, which may or may not be related to morphology, which itself requires monitoring.

Water quality affects a surfing resource's naturalness, reduces use and enjoyment, and in the worst case prevents access. Surfers immerse in the ocean environment for prolonged periods, when compared to the average user, which has the potential for increased exposure to water quality issues. Delta or bar breaks at tidal inlets or river mouths increase the risk of exposure, with a range of activities in the associated catchment, such as forestry and farming, being associated with water quality issues. Other sources include, but are not limited to, urban stormwater runoff, wastewater treatment and processing plant outlets, nearshore dredging, construction and aquaculture. In many countries, there are recreational/bathing water quality guidelines. Bathing areas are not always proximal to surfing areas and, to use the river mouth example, are not always safe for bathing. Water quality is a widely accepted component of the Assessment of Environmental Effects or Environmental Impact Assessment, establishing surf break usage against water quality parameters and associated trigger levels for consent is an area requiring further research.

User numbers can be related to the attributes of amenity value, level of use and, indirectly, economic value. Along with other value attributes, user numbers can be used to infer the significance of a surfing resource, should a managing authority, community group or other undertaking activities in the coastal zone require to do so. Understanding the value attributes users associate with a surfing resource helps establish the significance of a site, which may be useful to authorities in the allocation of resources, such as funding or equipment. User numbers may also provide insights into the economic value associated with a particular location. Monitoring user numbers may be required in places where overcrowding is a problem. At the time of writing, there are plans to regulate the number of users at the surf breaks on either side of Thanburudhoo in the Maldives, with paid-for, bookable time slots available to tourists (Ministry of Environment, Climate Change and Technology, 2022). Understanding the number of users would aid in developing the thresholds for a meaningful time slot length both in terms of user enjoyment/experience and surf break user capacity.

Peel angle has been shown to be one surfing wave quality parameter that can be readily monitored with a high frequency. Peel angle is considered the most important of surfing wave quality parameters, but the shape and length of the breaking wave are extremely important when it comes to establishing a baseline. A surfing resource that is known for high-performance surfing or barrel riding, or one that provides long rides, would not have the same value attributes if wave breaking happened in a spilling manner or a pier was constructed halfway along the wave. Monitoring breaking wave shape is an involved process and one that has rarely been undertaken. The only repeat monitoring of wave shape known to this author was undertaken by this author while studying the multipurpose reef constructed at Boscombe in the UK. Images perpendicular to the wave orthogonal, directed toward the breaking part of the wave, with the camera's GPS location concurrently recorded are required (Mead and Black, 2001c). A static camera could provide this type of data for very specific locations, but this is yet to be undertaken. In an ideal world, peel angle would be recorded simultaneously with wave breaking shape, which would provide a comprehensive picture for surfability and performance baselines.

Characterisation of ride length can be done heuristically with georeferenced aerial/satellite photography; however, these datasets are often temporally sparse. The advent of accessible drones means that aerial images can be collected very readily. Indeed, both peel angle and ride length could be collected by researchers almost autonomously, with daylight, weather conditions and aviation regulations providing sampling constraints.

GPS watches worn by surfers will always be constrained by ability and ride completion, and should be analysed against met-ocean conditions. Surfer GPS provides a range of datasets (e.g., Borrero *et al.*, 2019), including ride length, that can be used in surf break characterisation. Ride length was successfully extracted from the oblique imagery approach to surf break monitoring described in this thesis and probably provides the most comprehensive sampling method.

Detailed characterisation requires knowledge of the physical components that make up a surf break, which will require bathymetric data. Previous knowledge of surf break dynamics is imperative to the planning of bathymetric data collection to determine the extent and resolution of the survey required. It has been shown in this work (and references therein) that the bathymetry far from the surf break can modify incident wave conditions and strongly influence surfing wave quality. If local knowledge combined with expert interpretation, and examination of other resources (e.g., photographs), does not identify any notable or obvious bathymetric features conducive to surf break existence, investigators may require an iterative approach comprised of survey data collection and associated simulations, until the wave breaking patterns of the surf break are resolved.

An automated framework for consistently monitoring peel angle, wave shape and ride length could rely on the process of extracting bathymetric data from remote camera systems. cBathy (Holman *et al.*, 2013) is an algorithm that analyses multiple time series of pixel intensity extracted from image data cubes to isolate depth. Bathymetric data can be generated for every image cube acquired. The bathymetric data could be used to construct a numerical model, over which phase-resolved incident wave conditions can be simulated. The simulations would be validated against the wave breaking and peel angle tracking approach presented in Chapter 9. An objective estimate of ride length, that has no user error associated with GPS watches, could be extracted.

Wave shape could be obtained using the equation of Mead and Black (2001c). The orthogonal seabed gradient underneath the breaking part of the wave could be extracted either from the numerical model; or, using wave direction associated with the vector perpendicular to the wave crests which were identified through automated wave tracking (Chapters 8 and 9). A further option to visualise breaking wave shape is to use the extracted bathymetry in a higher-order numerical simulation such as a Computational Fluid Dynamics (CFD) model, where the use of particles allows the user to replicate the 3-dimensional process of breaking. While the level of complexity increases, having these options available is imperative, as not all sites and/or activities are the same, with some requiring extra detail to determine potential impacts. This system would, however, allow bathymetric changes and associated impacts on surfing wave quality to be tracked through time at a relatively high resolution.

An associated piece of future work is to automate a system to track bathymetric changes through time within the context of Mead and Black's (2001a, 2001b) functional components. Simple geometries of functional components, such as length and width, could provide trackable metrics, which can be related to surfing wave quality, as opposed to a qualitative assessment of the broader bathymetric changes.

Surf break monitoring data can provide other valuable information for coastal management. For instance, remote video cameras can provide statistics on users of the coastal space (not only surfers, but other water and beach users), erosion/accretion trends, the movement of rips and bars (e.g., safety issues), and information on extreme events and coastal hazards. There is an opportunity to incorporate surf break baseline data collection into any long-term environmental monitoring strategy.

10.10 Conclusion

This research aimed to improve surfing resource management by identifying and better understanding what critical components need to be considered. Based on literature review, stakeholder engagement, data collection, and the development of tools and techniques, a surfing resource was defined which encapsulates the broad categories that need to be considered, with a novel set of Management Guidelines for Surfing Resources (the Guidelines) both synthesising the findings of this work and providing details on these considerations.

This work has highlighted the importance of effective and meaningful stakeholder engagement, especially when considered within the context of the broad range of value attributes associated with surfing resources that are now being recognised. The management landscape outside ANZ is changing and the utility of the Management Guidelines for Surfing Resources as a point of reference for best practice has been evidenced. The Guidelines provide simple steps to follow for proponents, opponents and authorities dealing with activities in the coastal environment that may affect surfing resources. Effective surfing resource monitoring and investigation methods have been described and show how quantitative baseline datasets can be developed. In addition, the role of bathymetric features outside the surf zone that contribute to surfing wave quality have been investigated in detail, showing the importance of a surf break's swell corridor, for which an effective method of construction has been derived.

This body of work, appendices, and references show that the components required to comprehensively manage a surfing resource are wide and varied and will not be the same in each location. A one-size-fits-all approach does not apply to surfing resource management as the number of variables, from geophysical through to social, can change from one section of the coast to the next, this is compounded by the type and location of activities that may impact on surfing resources also being wide and varied.

Accurate surfing resource characterisation is imperative for sustainable management. Local knowledge combined with expert interpretation establishes a foundation from which characterisation can be established. Examination of literature and aerial photographs have been a vital resource in characterisation, specifically in identifying the nature of wave propagation at a site, and any historical changes.

All elements of this research either support or contribute to the understanding required for the effective implementation of the NZCPS, but also have value beyond ANZ. This work reiterates the importance of establishing environmental baselines, which will facilitate sustainable activities important to the social, economic and cultural well-being of people and communities (Policy 6, NZCPS). Appendix E provides a summary of the surf science and management setting in ANZ and introduces a not-for-profit trust, the Aotearoa New Zealand Association for Surfing Research (ANZASR), that was established following the overarching research project. The ANZASR has taken responsibility for the camera systems, associated database and Guidelines. The overriding vision of the ANZASR is to help keep ANZ at the forefront of surfing resource management.

Protection is a term used in legislation and is effective in enabling the recognition of a resource and facilitates proactive management. Other forms of effective recognition, such as surfing reserves, have shown value when it comes to conservation, but largely underpin or add credence to reactive management scenarios. Management is challenging in reactive scenarios, where a surfing resource is often only recognised by proponents and authorities through conservation efforts that try to address threats to the surf breaks integrity and/or usage. Effective management works best with proactive recognition (identification) of surfing resources and the areas they occupy, such as swell corridors containing offshore preconditioning features and the Surf Break Area and associated access points, ideally combined with established environmental baselines. Operationally, combining user experience and local knowledge with expert judgement informed by appropriate quantitative studies will provide the best management strategy and pathway to sustainable outcomes.

11 References

Armitano, C.N., Clapham, E.D., Lamont, L.S., and Audette, J.G., 2015. Benefits of Surfing for Children with Disabilities: A Pilot Study. Palaestra, 29(3), p.31-34.

Arnold, B.F., Schiff, K.C., Ercumen, A., Benjamin-Chang, J., Steele, J.A., Griffith, J.F., Steinberg, S.J., Smith, P., McGee, C.D., Wilson, R., Nelsen, C., Weisberg, S.B., Colford Jr., J.M., 2017. Acute Illness Among Surfers Following Dry and Wet Weather Seawater Exposure. American Journal of Epidemiology. 186 (7), p.866-875.

Arroyo, M., Levine, A. and Espejel, I., 2019. A Transdisciplinary Framework Proposal for Surf Break Conservation and Management: Bahía De Todos Santos World Surfing Reserve. Ocean and Coastal Management, 168, p.197-211.

Arroyo, M., Levine, A., Brenner, L., Seingier, G., Leyva, C. and Espejel, I., 2020. Indicators To Measure Pressure, State, Impact and Responses of Surf Breaks: The Case of Bahía De Todos Santos World Surfing Reserve. Ocean and Coastal Management, 194.

ASBPA, 2011. Surfers As Coastal Protection Stakeholders. Shore and Beach Science and Technology Committee white Paper, p.1-9.

Atkin, E.A., 2010. The Impact of An ASR on Breaking Wave Conditions at Boscombe, UK. Masters Thesis: University of Southampton, UK.

Atkin, E.A., 2017. Known Surfing Coastlines in The Waikato Region. Raglan, New Zealand: eCoast Marine Consulting and Research. Letter Report, WRC.

Atkin, E.A., 2021a. Advances in Research and Management of Surfing Resources. Coastal News, 76.

Atkin, E.A., 2021b. Machine-learned Peel Angles for Surfing Wave Quality Monitoring. In Proceedings of the 25th Australasian Coasts and Ports Conference – Christchurch, New Aotearoa Zealand, 11-13 April 2022.

Atkin, E.A., Davies-Campbell, J. and McIntosh, R., 2022. Deep Learning Object Detection Application to Surfing Wave Quality. Coastal Engineering, 37.

Atkin, E.A., Bryan, K., Mead, S.T., Hume, T. and Waiti, J., 2019. Management Guidelines for Surfing Resources. In Proceedings of the 24th Australasian Coasts and Ports Conference – Hobart, Australia, 10-13 September 2019, p. 42-48.

Atkin, E.A. and Greer, D., 2013. Analysis of Bathymetric Surveys, Wave Climate, Breaking Patterns and Wave Driven Circulation at Whangamata Ebb Tidal Delta. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research.

Atkin, E.A. and Greer, D., 2019. A Comparison of Methods for Defining a Surf Break's Swell Corridor. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.

Atkin, E.A., Greer, S. and Pickett, V., 2013. Whangamata Ebb Tidal Delta Morphology and Wave Breaking Patterns. In Coasts and Ports 2013: 21st Australasian Coastal and Ocean Engineering Conference and the 14th Australasian Port and Harbour Conference, p.18-22.

Atkin, E.A., Gunson, M. and Mead. S. T., 2015. Regionally Significant Surf Breaks in the Greater Wellington Region. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research.

Atkin, E.A., Hume, T., Bryan, K., Mead, S.T. and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance: Initial Characterisation of Study Sites. Raglan, Aotearoa New Zealand: Surf Break Research.

Atkin, E.A. and Mead, S.T., 2017. Surf Breaks of Regional Significance in the Waikato Region. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research, 75p.

Atkin, E.A., Mead, S.T., Bryan, K., Hume, T. and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National And Regional Significance. In Proceedings of the 23rd Australasian Coasts and Ports Conference – Cairns, Australia, 21-23 June 2017, p. 13-19.

Atkin, E.A.; Mead, S.T., and Phillips, D., 2019. Investigations of Offshore Wave Preconditioning. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 78–90. Coconut Creek (Florida), ISSN 0749-0208.

Atkin, E.A., O'Connell-Milne, S., Mead, S.T. and Davies-Campbell, J. 2021. Surf Breaks of Regional Significance: Southland. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research.

Atkin, E.A., Reineman, D.R., Reiblich, J. and Revell, D.L., 2020. Applicability of Management Guidelines for Surfing Resources in California. Shore & Beach, 88(3), pp.53-64.

Ball, S., 2015. The Green Room: A Surfing-Conscious Approach to Coastal and Marine Management. UCLA Journal of Environmental Law and Policy, 33(2).

Bancroft, S., 1999. Performance Monitoring of the Cables Station Artificial Surfing Reef. Doctoral Thesis, University of Western Australia, Department of Environmental Engineering, Australia.

Battalio, B., 1994. Estimating Braking Wave Height at Ocean Beach, San Francisco. Shore and Beach, 62(4).

Battalio, R.T. and Trivedi, D., 1996. Sediment Transport Processes at Ocean Beach, San Francisco, California. Coastal Engineering, 25, p.2691-2704.

Battjes, J. A., 1974. Surf Similarity. Coastal Engineering Proceedings, 1(14). p.466-480.

Beamsley, B.J. and Black, K.P., 2003. The Effect of offshore Reefs on Inshore Surfing Conditions. Proceedings of the 3rd International Surfing Reef Conference. Raglan, New Zealand.

Beattie, H. 1919. Traditions and legends collected from the natives of Murihiku (Southland, New Zealand). The Journal of the Polynesian Society, 28(XI), 212–25.

Benedet, L., Finkl, C.W. and Hartog, W.M., 2007. Processes Controlling Development of Erosional Hot Spots on A Beach Nourishment Project. Journal of Coastal Research, 23(1), p.33-48.

Best, E. 1924. Games and pastimes of the Māori. Wellington, New Zealand: A. R. Shearer.

Bhana, M., 1996. New Zealand Surfing Guide. Revised Ed. Auckland: Reed Books.

Black, K. P., J. A. Hutt and S. T. Mead, 1998. Narrowneck Reef Report 2: Surfing Aspects. Raglan, Aotearoa New Zealand: ASR Ltd.

Black, K. P., 2007. Review of Wave Hub Technical Studies: Impacts on Inshore Surfing Beaches. Raglan, Aotearoa New Zealand: ASR Ltd.

Blacka, M.J., Shand, T.D., Carley, J.T. and Mariani, A., 2013. A Review of Artificial Reefs for Coastal Protection in NSW. Manly, Australia: Water Research Laboratory.

Blum, M., 2015. Protecting Surf Breaks and Surfing Areas in California. Masters Thesis: Duke University Nicholas School of the Environment, USA.

Blum, M.L. and Orbach, M.K., 2021. First Steps at First Point: Protecting California Surf Breaks and the Malibu Historic District. Coastal Management, 49(2), p.201-214.

Borne, G. and Ponting, J., (Eds) 2017. Sustainable Surfing. Routledge, Oxon and NY. 261pp.

Borrero, J., Rifai, J. and O'Day, C., 2019. Scientific and Commercial Applications of Rip Curl Search GPS Watch Data. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 55–69. Coconut Creek (Florida), ISSN 0749-0208.

CCC, 2018. Updated Sea Level Rise Policy Guidance. November 2018. California Coastal Commission.

Caddick, N., Smith, B. and Phoenix, C., 2015. The Effects of Surfing and the Natural Environment on the Well-Being of Combat Veterans. Qualitative Health Research, 25(1), p.76-86.

Campbell, O., 2021. Exploring How New Zealand Surfers Construct Experiences of the Coastal Environment. Masters Thesis: Lincoln University, Aotearoa New Zealand.

Christensen, S. and Baker, M., 2007. Fish Hooks in the Marina Decision. Resource Management Journal, April, .1-6.

City of Gold Coast, 2015. Gold Coast Surf Management Plan. Gold Coast, Australia: City of Gold Coast

Clapham, E.D., Armitano, C.N., Lamont, L.S. and Audette, J.G., 2014. The Ocean as a Unique Therapeutic Environment: Developing a Surfing Program. Journal of Physical Education, Recreation and Dance, 85(4), p.8-14.

Clifton, C.A., Ware, D., Coverdale, S. and Hanson-Boyd, C., 2013. Climate Change Risks for Victoria's Surf Coast. In Coasts and Ports 2013: 21st Australasian Coastal and Ocean Engineering Conference and the 14th Australasian Port and Harbour Conference.

Coombes, K., and Scarfe, B., 2010. Draft Auckland Regional Policy Statement Background Report – Surf Breaks. Auckland, New Zealand: Environmental Policy and Planning (ARC), 37p.

Corne, N.P., 2009. The Implications of Coastal Protection and Development on Surfing. Journal of Coastal Research, 25(2), p.427-434.

Danish Hydraulic Institute, 2016. Wellington Airport Runway Extension Surf Break Impact Assessment: Numerical Modelling, Preliminary Mitigation Investigations and Feasibility Study. Auckland, Aotearoa New Zealand: DHI Water and Environment Ltd.

Davies-Campbell, J., 2018. The Morphology and Surf Conditions of Aramoana Beach, Otago: A Surf Break of National Significance. Master Thesis: University of Waikato, Aotearoa New Zealand.

Davis, R.M., 2009. Short History of Otago Harbour Development and Dredging. Dunedin, Aotearoa New Zealand: Duffill Watts Ltd.

Department of Conservation, 2009. Proposed New Zealand Coastal Policy Statement 2008 Report and Recommendations Volume 2: Working Papers. Aotearoa New Zealand: Department of Conservation.

Department of Conservation, 2011. NZCPS 2010 Guidance note Policy 16: Surf Breaks of National Significance. Aotearoa New Zealand: Department of Conservation.

Dredging Today, 2012. Port Hacking Sand Relocated to North Cronulla Beach (Australia). Dredging Today. Available at: https://www.dredgingtoday.com/2012/09/06/port-hacking-sand-relocated-to-north-cronulla-beach-australia/ (Accessed 11 May 2020).

Edwards, A.M., 2013. Surf Break Co-Management: Options for the Protection and Enhancement of Surf Breaks in New Zealand. Masters Thesis: Otago University, Aotearoa New Zealand.

Ewans, K.C., 2002. Directional Spreading in Ocean Swell. Ocean Wave Measurement and Analysis, 2001, p. 517-529.

Farmer, B. and Short, A.D., 2007. Australian National Surfing Reserves–Rationale and Process for Recognising Iconic Surfing Locations. Journal of Coastal Research, Special Issue 50, p.99-103.

Galvin, C.J., 1968. Breaker Type Classification on Three Laboratory Beaches. Journal of Geophysical Research 73, 3651-3659.

Gilje, H.L., 2018. Surfonomics: The Value of a Wave. Masters Thesis: University of Stavanger, Norway.

Hearin, J., 2009. Preliminary Design of an Artificial Surfing Reef for Cocoa Beach, Florida. Reef Journal. 1 (1).

Hewett, B., 2011. Opportunities for Improved Surfbreak Management in New Zealand. Bachelor Thesis: Massey University, Palmerston North

Hicks, D.M. and Hume, T.M., 1996. Morphology and Size of Ebb Tidal Deltas at Natural Inlets on Open-Sea and Pocket-Bay Coasts, North Island, New Zealand. Journal of Coastal Research, 12(1), p.47-63.

Hignett, A., White, M.P., Pahl, S., Jenkin, R. and Le Froy, M., 2018. Evaluation of a Surfing Programme Designed to Increase Personal Well-Being and Connectedness to the Natural Environment Among 'at Risk' Young People, Journal of Adventure Education and Outdoor Learning, 18(1), p.53-69.

Holman, R., Plant, N. and Holland, T., 2013. cBathy: A Robust Algorithm for Estimating Nearshore Bathymetry. Journal of Geophysical Research: Oceans, 118(5), pp.2595-2609.

Hume, T.M.; Mulcahy, N., and Mead, S.T, 2019. An overview of changing usage and management issues in New Zealand's surf zone environment. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 1–12. Coconut Creek (Florida), ISSN 0749-0208.

Hutt, J. A., Black, K. P. and Mead, S. T., 2001. Classification of Surf Breaks in Relation to Surfing Skill. In: Black, K.P. (Ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research, Special Issue 29, p.66-81.

Iribarren, C. R., and Nogales, C., 1949. Protection Des Ports. Section II, Comm. 4, Xviith Inter. Naval Cong., 31-80.

Jocher *et al.* 2020. Ultralytics/yolov5. Version v3.0. DOI: 10.5281/zenodo.3983579

Johnson, C.M., 2009. The Effect of Artificial Reef Configuration on Wave Breaking Intensity Relating to Recreational Surfing Conditions. Masters Thesis: Stellenbosch University, South Africa.

Karimi, D., Dou, H., Warfield, S.K. and Gholipour, A., 2020. Deep Learning with Noisy Labels: Exploring Techniques and Remedies Medical Image Analysis, 65.

Kilpatrick, D., 2005. Determining Surfing Break Components at Aramoana Beach, Dunedin. Otago, New Zealand. Thesis: University of Otago, Aotearoa New Zealand.

Lazarow, N., 2007. The Value of Coastal Recreational Resources: A Case Study Approach to Examine the Value of Recreational Surfing to Specific Locales. Journal of Coastal Research, Special Issue 50, p.12-20.

Lazarow, N., Miller, M.L. and Blackwell, B., 2008. The Value of Recreational Surfing to Society. Tourism in Marine Environments, 5(2-3), p.145-158.

Liria, P., Garel, E. and Uriarte, A., 2009. The Effects of Dredging Operations on the Hydrodynamics of an Ebb Tidal Delta: Oka Estuary, Northern Spain. Continental Shelf Research, 29(16), p.1983-1994.

MSL, 2014. Port Otago Dredge Disposal Grounds. Raglan, Aotearoa New Zealand: Metocean Solutions Ltd.

Mach, L., and Ponting, J., 2021. Establishing A Pre-COVID-19 Baseline for Surf Tourism: Trip Expenditure and Attitudes, Behaviours and Willingness to Pay for Sustainability. Annals of Tourism Research Empirical Insights, 2(1).

Martin, S.A., 2010. Coastal Resource Assessment for Surf Tourism in Thailand. Masters Thesis, Prince of Songkla University, Thailand.

Martin, S.A., 2012. The Conservation of Coastal Surfing Resources in Thailand. Doctoral Thesis: Prince of Songkla University, Thailand.

Martin, S.A. and Assenov, I., 2014. Measuring the Conservation Aptitude of Surf Beaches in Phuket, Thailand: An Application of the Surf Resource Sustainability Index. International Journal of Tourism Research, 17(2), p.105-117.

Martin, S.A. and O'Brien, D., 2017. Surf Resource System Boundaries. In: Borne G. and Ponting, J. (eds). Sustainable Surfing. Routledge London and New York.

McGregor, T. and Wills, S., 2016. Natural Assets: Surfing a wave of economic growth. Oxford, UK: Centre for the Analysis of Resource Rich Economies.

McGregor, T. and Wills, S., 2017. Surfing A Wave of Economic Growth. CAMA Working Paper Sydney, Australia: University of Sydney, School of Economics.

Mcintosh, R., Atkin, E.A. and Davies-Campbell, J. Development of An Automated Peel Angle Detection System for the Manu Bay Surf Break. New Zealand Coastal Society. New Zealand Coastal Society Conference, Gisborne.

McNeil, M. and Coombes, K., 2012. Surf break provisions in the Auckland Council unitary plan – draft. Auckland, Aotearoa New Zealand: Auckland Council.

Mead, S. T., 2000. Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs. Doctoral Thesis: University of Waikato, Aotearoa New Zealand.

Mead, S.T., 2008. Evidence Of Shaw Trevor Mead: In Support of Written Submission and The Surfbreak Protection Society Incorporated. Department of Conservation Board of Enquiry.

Mead, S.T., 2013. Potential Effects of Trans-Tasman Resources Mining Operations on Surf Breaks in the Southern Taranaki Bight. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research.

Mead, 2019. Statement of Evidence of Shaw Trevor Mead: In the matter of Application for a new coastal permit to operate a spat farm in Whauwhau, Whitianga. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research.

Mead, S.T., 2020. The Influence of Manu Bay Boatramp/Breakwater on Coastal Processes and Downcoast Erosion. eCoast Technical Report prepared for Waikato District Council.

Mead, S.T. and Atkin, E.A., 2019. Managing issues at Aotearoa New Zealand's surf breaks. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New

Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 13–22. Coconut Creek (Florida), ISSN 0749-0208.

Mead S.T. and Atkin, E.A, 2022. Morphological Response of the Nearshore Seabed due to Offshore Preconditioning Features. In preparation. Coastal Engineering, 180.

Mead, S. T., Atkin, E. and Phillips, D. J., 2011. Preliminary Investigation of offshore Focusing Reefs. Raglan, Aotearoa New Zealand: eCoast Marine Consulting and Research.

Mead, S.T., Atkin, E.A., Hume, T., Bryan, K. and Waiti, J., 2021. The Application of Surf Science and Coastal Oceanography to Develop Win-Win Scenarios for Sustainable Development and Management of Marine Resources. Australasian Coasts and Ports 2021 Conference Proceedings.

Mead, S.T. and Black, K.P., 2001a. Field Studies Leading to the Bathymetric Classification of World-Class Surfing Breaks. In: Black, K.P (eds) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research, Special Issue 29, p.5-20.

Mead, S.T. and Black, K. P., 2001b. Functional Component Configurations Controlling Surfing Wave Quality at World-Class Surfing Breaks. In: Black, K.P (eds) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research, Special Issue 29 p.21-32.

Mead S.T. and Black, K. P., 2001c. Predicting the Breaking Intensity of Surfing Waves. In: Black, K.P (eds) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research, Special Issue 29, p.51-65.

Mead, S.T., Black, K.P.; Frazerhurst, J. and Scarfe, B., 2003. The Effects of Wave Focusing on Surfing Reef Site Selection, Surfing Wave Quality and ASR Design at Scales of Inner Continental Shelf to Sub-Tidal Reef. 3rd International Artificial Surfing Reef Symposium, Raglan, New Zealand.

Mead, S.T. and Borrero, J., 2017. Surf Science and Multipurpose Reefs. In Green, D.R. and Payne, J.L. (eds.), Marine and Coastal Resource Management: Principals and Practice. p. 288–311. Abingdon: Routledge.

Marteleira, R., Bicudo, P., De Brito, A.G. and Coelho, P.S., 2018. Surfing Safe Waves: Integration of Water Quality Modelling in the Evaluation of Potential Health Risks. International Journal of Hydrology Science and Technology, 8(2), p.105-119.

Mesa, C., 1996. Nearshore Berm Performance. Proceedings of the 25th International Conference on Coastal Engineering.

Ministry for the Environment, 2017. Coastal Hazards and Climate Change: Guidance for Local Government. Wellington: Ministry for the Environment. ISBN: 978-1-98-852535-8.

Ministry of Environment, Climate Change and Technology, 2022. Management Plan for the Protection and Conservation of the Thanburudhu Area. Republic of Maldives.

Monteferri, B., Scheske, C. and Muller, M.R., 2019. The Legal Protection of Surf Breaks: An Option for Conservation and Development. In: Muller, R., Oyanedel, R. and Monteferri, B (eds) Marine and Fisheries Policies in Latin America. p.149-162). London, UK: Routledge.

Moores, A., 2001. Using Video Images to Quantify Wave Sections and Surfer Parameters. Masters Thesis: University of Waikato, New Zealand.

Morse, P.B. and Brunskill, P., 2004. Wavetrack New Zealand Surfing Guide. Greenroom Surf Media Ltd, Mount Maunganui.

Northland Regional Council, 2016a. Application of Methodology. Identifying Regionally Significant Surf Breaks in Northland. Whangarei: Northland Regional Council, 12.

Northland Regional Council, 2016b. Methodology – Identifying Regionally Significant Surf Breaks in Northland. Whangarei: Northland Regional Council, 14.

NZS, 2014. The Big Wave Challenge 1999-2002. New Zealand Surfing, 158.

Nelsen, C., Cummins, A., and Tagholm, H., 2013. Paradise Lost: Threatened Waves and the Need for Global Surf Protection. Journal of Coastal Research, 65 (International Coastal Symposium 1), p.904-908.

Nelsen, C., Pendleton, L., and Vaughn, R., 2007. A Socioeconomic Study of Surfers at Trestles Beach. Shore and Beach, 75(4), p.32–37.

Neubauer, T., 2006. How Proximity to A High Quality Surf Break Affects Land and Property Values. Raglan, Aotearoa New Zealand: ASR Ltd.

Orams, M.B. and Towner, N., 2012. Riding the wave: History, definitions, and a proposed typology of surf-riding tourism. Tourism in Marine Environments, 8(4), pp.173-188.

Orchard, S., 2017a. Lessons for the Design of Surf Resource Protection–the Australasian Experience. Ocean and Coastal Management, 148, .104-112.

Orchard, S., 2017b. Regional Significance Criteria for the Assessment of Surf Breaks. Report Prepared for Taranaki Regional Council. 27p.

Orchard, S., Atkin, E.A. and Mead, S.T., 2019. Development of the Regional Significance Concept for Surf Break Management in Aotearoa New Zealand. In: Bryan, K.R. and

Atkin, E.A. (Eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue 87, p.23–34. Coconut Creek (Florida), ISSN 0749-0208.

Pearce, G., 2013. Whangamata Ebb Tide Bar, Monitoring Report. Aotearoa New Zealand: Tonkin and Taylor.

Peirão, R. and Santos, S.G.D., 2012. Judging criteria in international professional surfing championships. Revista Brasileira de Cineantropometria & Desempenho Humano, 14, pp.439-449.

Peryman, B., 2011a. Surf Break Identification and Protection in the Gisborne District. Gisborne, Aotearoa New Zealand: Gisborne District Council.

Peryman, B., 2011b. Identification of Surf Breaks of National Significance. Lincoln Planning Review, 3 (1).

Peryman, B., 2011c. Bay of Plenty Surf Break Study. Aotearoa New Zealand: Bay of Plenty Regional Council.

Peryman, P.B., and Orchard, S., 2013. Understanding the Values and Management Needs of New Zealand Surf Breaks. Lincoln Planning Review, 4(2): 8-18.

Peryman, P.B. and Skellern, M., 2011. Planning Tools for Surf Breaks. Coastal News, 46

Phillips, D.J. and S.T. Mead, 2008. Investigation of a Large Offshore Sandbar at Raglan, New Zealand: Impacts on Surfing Amenity. Shore and Beach, 76(2).

Pitt, A., 2009. Surfing at Bombora Controlled Beaches. The 5th Western Australia Coastal Conference, Freemantle, WA.

Pitt, A., 2010. Proposal for An Ephemeral Bombora at Cronulla. 19th NSW Coastal Conference 2010.

Pitt, A. 2012. Wave Focusing Sand Slug…An Update. Cronulla, Australia.

Ponting, J., 2006. Castles Made of Sand: T the 'Nirvanification' of the Mentawai Islands. in Proceedings of the International Tourism and Media Conference, 28, p.167-176.

Puriri, K., 2015. Surf Into Summer: The Point. Raglan, Aotearoa New Zealand: Raglan Chronicle.

Raichle, A. W., 1998. Numerical Predictions of Surfing Conditions at Mavericks, California. Shore and Beach, 66, p.26-30.

Rainger, T., 2011. The New Zealand Good Beach Guide: North Island. Raglan, Aotearoa New Zealand: Clean Media Ltd.

Ratten, V., 2018. Social Innovation in Sport: The Creation of Santa Cruz as a World Surfing Reserve. International Journal of Innovation Science.

Reiblich, J., 2013. Greening the Tube: Paddling Toward Comprehensive Surf Break Protection. Environs: Environmental Law and Policy Journal, 37.

Reineman, D.R., Thomas, L.N. and Caldwell, M. R., 2017. Using Local Knowledge to Project Sea Level Rise Impacts on Wave Resources in California. Ocean and Coastal Management, 138, p.181-191.

Rennie, H.G., 2018. The Seduction of Fast Track Recovery Legislation – The Mangamaunu Surf Break Saga. Planning Quarterly, 211, p. 21-27.

Riley, P.B., Monro, I.S. and Schofield J. C., 1985. Late Holocene Sedimentation in Omaha Bay, North Island, New Zealand, New Zealand Journal of Geology and Geophysics, 28(2), p.299-312.

Román, C., Borja, A., Uyarra, M. C., and Pouso, S., 2022. Surfing the Waves: Environmental and Socio-Economic Aspects of Surf Tourism and Recreation. Science of the Total Environment, 826.

Rooney, E., 2011. Them's the Breaks. Auckland, Aotearoa New Zealand: NZ Herald (Aucklander).

Rust, R. and Kirkham, C., 2009. Riding Giants. New Zealand Geographic, 99.

SAS, 2009. Guidance on Environmental Impact Assessment of Offshore Renewable Energy Development on Surfing Resources and Recreation. St Agnes, UK: Surfers Against Sewage.

Sayce, A.J., 1997. Transformation of Surfing Waves Over Steep and Complex Reefs. Masters Thesis: University of Waikato, Aotearoa New Zealand.

Sayce, A.J., Black, K.P., and Gorman, R., 1999. Breaking Wave Shape on Surfing Reefs. Proceedings of Coasts and Ports ’99 Conference, 2, p.596-603.

Scarfe, B.E. 1999. Hydrography and Photogrammetry: Tools for Artificial Surfing Reef Studies. MSc Dissertation, University of Otago, New Zealand.

Scarfe, B., 2008. Oceanographic Considerations for the Management and Protection of Surfing Breaks. Doctoral Thesis: University of Waikato, Aotearoa New Zealand.

Scarfe, B. E., Elwany, M. H. S., Mead, S.T. and Black, K. P., 2003a. The Science of Surfing Waves and Surfing Breaks - A Review. Proceedings of the 3rd International Surfing Reef Symposium, Raglan, New Zealand, June 22-25, 2003. p.37-59.

Scarfe, B.E., Elwany, M.H.A., Mead, S.T. and Black, K.P., 2003b. The Science of Surfing Waves and Surfing Breaks - A Review. Scripps Institution of Oceanography Technical Report.

Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T., 2009a. Sustainable Management of Surfing Breaks: An Overview. Reef Journal, 1(1), p.44–73.

Scarfe, B.E., Healy, T.R. and Rennie, H.G., 2009b. Research-Based Surfing Literature for Coastal Management and the Science of Surfing—A Review. Journal of Coastal Research, 25(3), p.539-557.

Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T., 2009c. Sustainable Management of Surfing Breaks: Case Studies and Recommendations. Journal of Coastal Research, 25(3), p.684-703.

Scorse, J. and Hodges, T., 2017. The Non-Market Value of Surfing and its Body Policy Implications. In: Borne G. and Ponting, J. (eds). Sustainable Surfing. Routledge London and New York, 261p.

Scorse, J., Reynolds III, F. and Sackett, A., 2015. Impact of Surf Breaks on Home Prices in Santa Cruz, CA. Tourism Economics, 21(2), p.409-418.

Scott, S.Q. and Rogers, S.H., 2018. Surf's up? How Does Water Quality Risk Impact Surfer Decisions? Ocean & Coastal Management, 151, p.53-60.

Shand, T., 2008. Whangamata Marina Numerical Model Development and Reporting. Aotearoa New Zealand: Tonkin and Taylor.

Shand, T., Reinen-Hamill, R., Weppe, S. and Short, A., 2019. Development of a Framework for Assessing Effects of Coastal Engineering Works on a Surf Break. In Proceedings of the 24th Australasian Coasts and Ports Conference – Hobart, Australia, 10-13 September 2019.

Skellern, M., 2011. Planning for Sustainable Waves. Australasian Parks and Leisure, 14(1), p.32–33.

Skellern, M., Peryman, B., Orchard, S., and Rennie, H., 2013. Planning Approaches for the Management of Surf Breaks in New Zealand. Auckland: Auckland University, Auckland Council, Bay of Plenty Regional Council and Surfbreak Protection Society of New Zealand. P. 98

Soller, J.A., Schoen, M., Steele, J.A., Griffith, J.F. and Schiff, K.C., 2017. Incidence of Gastrointestinal Illness Following Wet Weather Recreational Exposures: Harmonization of Quantitative Microbial Risk Assessment with an Epidemiologic Investigation of Surfers. Water Research, 121, pp.280-289.

Steele, J.A., Blackwood, A.D., Griffith, J.F., Noble, R.T. and Schiff, K.C., 2018. Quantification of Pathogens and Markers of Faecal Contamination During Storm Events Along Popular Surfing Beaches in San Diego, California. Water Research, 136, pp.137-149.

Surf Coast Shire, 2015. Bells Beach Surfing Recreation Reserve Coastal Management Plan 2015-2025. Torquay: Surf Coast Shire

Taranaki Regional Council, 2017. Online Wave Survey Data Analysis and Proposed Regionally Significant Surf Breaks. New Plymouth, Aotearoa New Zealand: Taranaki Regional Council.

The SWAN Team, 2020. SWAN User Manual. SWAN Cycle III Version 41.31A. Delft University of Technology, Delft, 143 p.

Thomberson, J., 2012. Honouring Past Struggles: Whangamata Protest 2008. Available Online: Https://Iso.Org.Nz/2012/08/12/Honouring-Past-Struggles-Whangamata-Protest-2008/

Walker, J.R., 1974. Wave Transformations Over a Sloping Bottom and Over a Three-Dimensional Shoal. Doctoral Thesis: Hawaii: University of Hawaii, USA.

Walker, J.R., Palmer, R.Q. and Kukea, J.K., 1972. Recreational Surfing on Hawaiian Reefs. Proceedings of the 13th Coastal Engineering Conference. Coastal Engineering, 1(13), p147.

Wannasurf, 2022. Omaha via Internet Archive Wayback Machine. Available Online: https://web.archive.org/web/20090911131048/http://www.wannasurf.com/spot/Australia_Pacific/New_Zealand/New_Zealand_NI/NE_Coast/omaha/comment/index.html?wdaction=lib.WDPageComment.show

Ware, D., Lazarow, N. and Hales, R., 2017. Surfing Voices in Coastal Management: Gold Coast Surf Management Plan–A Case Study. In: Borne G. and Ponting, J. (eds). Sustainable Surfing. London: Routledge, p.107-124.

West, A., 2002. Wave Focusing Surfing Reefs: A New Concept. Masters Thesis: Delft University of Technology, Netherland

West, A., Cowell, P., Battjes, J. A., Stive, M. J. F., Doorn, N. and Roelvink, J. A., 2003. Wave Focusing Surfing Reefs: A New Concept. Proceedings of the 3rd International Surfing Reef Conference. Raglan, New Zealand

Wheaton, B.; Roy, G.; Olive, R., 2017. Exploring Critical Alternatives for Youth Development Through Lifestyle Sport: Surfing and Community Development in Aotearoa/New Zealand. Sustainability, 9.

Wiegel, R. L., 1964. Oceanographical Engineering. New Jersey: Prentice-Hall.

Williamson, L and Williamson, M., 2014. Sands of Time: Ti Point Bar – the Making and Breaking of a Legend. [Online]. Available at: https://static1.squarespace.com/static/5c44f9303c3a53c04e1f5db7/t/5c5228e1032be4e2d7f8d717/1548888343103/TiPointEdit_Feb14.pdf

Wycherley, G., 2003. Law Blamed for Marina Marathon. [Online]. Available at: https://www.nzherald.co.nz/nz/law-blamed-for-marina-marathon/OD56FZAVJZ6EUCG7RWBKWXA7AA/

Zane, W.W., 1992. Surfers of Southern California: Structures of Identity. Masters Thesis: McGill University, Montreal.

Appendix A. Management Guidelines for Surfing Resources

The publisher has been granted permission to reproduce this article in the published format. Pagination of the reproduced article is carried over from publication and not synchronised with the main body of this thesis.

AOTEAROA NEW ZEALAND ASSOCIATION FOR SURFING RESEARCH

Management Guidelines for Surfing Resources

www.anzasr.org

Authors

Edward Atkin (eCoast Marine Consulting and Research)

Professor Karin Bryan (University of Waikato)

Dr Terry Hume (Hume Consulting Ltd)

Dr Shaw Mead (eCoast Marine Consulting and Research)

Dr Jordan Waiti (University of Waikato)

Advisers and Reviewers

This document has been peer reviewed by leading surf break management and preservation practitioners, and experts in coastal processes, planning and policy. Many thanks to Amy Robinson, Professor Andrew Short, Graeme Silver, Dr Greg Borne, Associate Professor Hamish Rennie, James Carley, Karen Bell, Matt McNeil, Michael Gunson, Rick Liefting, Dr Shaun Awatere, Dr Shane Orchard and Dr Tony Butt.

Supported by:

Department of Conservation
Te Papa Atawhai

Re-Published March 2023 by the Aotearoa New Zealand Association for Surfing Research, Raglan, New Zealand.

ISBN: 978-0-473-67336-9

Document available from: www.anzasr.org/management-guidelines

This document may be referenced as:

Atkin, E.A., Bryan, K.R., Hume, T.M., Mead, S.T., and Waiti, J.T.A., 2023. Management Guidelines for Surfing Resources. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research.

Disclaimer

These guidelines have been prepared by researchers from University of Waikato, eCoast Marine Consulting and Research, and Hume Consulting Ltd, under the guidance of a steering committee comprising representation from: Auckland Council; Landcare Research; Lincoln University; Waikato Regional Council; Surfbreak Protection Society; and, Surf Life Saving New Zealand. As well as providing a steering committee member, the Department of Conservation support the content and purpose of these guidelines.

These guidelines should not be taken as providing a definitive statement for any particular user's circumstances. It is an overall recommendation that users seek expert advice in both the management of surfing resources and the use of these guidelines. As new techniques and approaches are established, they will be incorporated into revised editions of these guidelines. Feedback on the content and use of these guidelines is welcome and can be provided via email: info@anzasr.org

Contents

Figures

Tables

1 Introduction

These guidelines provide background information and specific methodologies to assist in the sustainable management of surfing resources. The guidelines are aimed at assisting:

- authorities charged with implementing policies and plans,
- resource users and applicants to manage expectations and responsibilities with respect to resource consent requirements where proposed activities may affect surfing resources.
- stakeholders to understand how developments might affect the amenity value of surf breaks and the responsibilities of those proposing the developments.

The guidelines are one product of a 3-year research project funded by the Ministry of Business, Innovation and Employment (MBIE) (Atkin *et al.*, 2017). While the content of this document has been informed by consultation with stakeholders, a steering committee and independent reviewers, the final content is that of the authors.

1.1 Background

Surfing is a watersport where the participant is propelled along by a wave. The history of surfing is long compared to many sports, with Polynesians partaking in wave riding well before European contact. Joseph Banks, aboard HMS Endeavour while visiting Tahiti during the first voyage of James Cook, reported seeing Maohi (Indigenous Tahitians) riding wooden boards. In Aotearoa New Zealand surfing was a past time of the Māori people. It was carried out using a variety of craft, including boards, or kopapa, and even bags of kelp (poha) (Beattie, 1919; Best, 1924).

Interest in surfing grew following demonstrations to Wellington locals by the Hawai'ian surfer Duke Kahanamoku in 1915 (Figure 1.1). By the 1920s and 1930s in Aotearoa New Zealand, people were riding solid wooden boards and the Surf Life Saving movement began using heavy plywood skis to paddle through the surf and assist in rescues. In 1958 a visit to Piha by two American lifeguards, Bing Copeland and Rick Stoner, introduced the concept of surfing on smaller boards and riding across the face of the wave and helped locals to manufacture their own boards. By the late 1960s, the surfboard building industry was flourishing and building boards that allowed greater speed and more complex manoeuvres.

Figure 1.1: Duke Kahanamoku (left; Macmillan Brown Library, 2017) introduced surfing from Hawaii to Aotearoa New Zealand in 1915. The right image shows Duke with Ngati Tuwharetoa chief Te Heuheu Tukino V (from Osmond, 2010).

Today the growing numbers of people surfing has arisen from advances in technology bringing an ever-growing diversity of surf equipment including long boards, short boards, body boards, Stand Up Paddleboards (SUPs) and foil boards; tide and wave forecasting services via the worldwide web and mobile devices that allow users to target specific locations and sea states; and equipment such as wetsuits allowing activities to continue throughout the winter. The growth in surfing as an activity has been accompanied by the development of a surf culture reflected in the people, language fashions and lifestyle of participants.

Today surfers can no longer be simply regarded as “surf bums”. They appreciate their surf breaks and environment not just for the waves but also for spiritual and cultural aspects and because of this they have a strong sense of ownership of surf breaks (Usher, 2017). They represent a wide cross section of society and as frequent visitors to the coast have an inherent understanding of coastal processes and can play a valuable role as coastal protection stakeholders (ASBPA, 2011).

Surf breaks are unique and valuable components of the coastal environment. They have cultural, spiritual, recreational, economic and sporting value for many people. They are highly utilised assets that contribute to tourism, economic development and amenity values. Surfing has experienced rapid growth over the last three decades. Economists McGregor and Wills (2016) indicated that surf breaks contribute more than US$50 billion to global economic activity each year, and that recognition by the international surfing community of a new surf break can result in up to 3% economic growth in the area. In Aotearoa New Zealand, surfing is an important component of the large tourism industry, both for experienced international surfers looking to surf the world-class breaks and have the remote wilderness experience that is increasingly hard to find overseas, and for the surfing lessons/beginner industry.

The demand for space and resourcing around surf breaks and the recognition of their value has resulted in surf breaks becoming increasingly recognised in Aotearoa New Zealand coastal resource management. This is consistent with developments occurring internationally (see Ball (2015) and references therein).

An increased focus on mechanisms to protect surf breaks has followed from numerous cases of degradation worldwide, including human activities that compromise wave quality, access to breaks, water quality, and associated landscape, social and cultural features (Scarfe *et al*., 2009a, 2009b). The argument of those who openly wish to protect and preserve the integrity of surf breaks, such as the surf break Protection Society[1], Save the Waves[2] Surfrider Foundation[3] and Surfers Against Sewage[4], recognises that a range of benefits are associated with these unique places that transcend the recreational value of just "riding the wave". These benefits depend on maintaining the integrity of natural processes that influence surf break environments, and on a variety of aspects important to surf break users including accessibility and environmental health (Peryman and Orchard, 2013) and their sustainable management (Scarfe *et al*., 2009a,b; Borne and Ponting, 2017; Borne, 2018).

The management of surf breaks in other countries has been addressed by, for example, the creation of Surfing Reserves in Australia since 2006, laws passed in Hawaii in 2010 to protect breaks on Oahu and the World Surfing Reserves (WSR) programme[5] launched in 2009. The WSR programme works by way of a self-nomination process, whereby communities can apply to Save The Waves to be considered for designation, and the application undergoes a review that considers the wave(s), surrounding environment, culture and surfing history, and capacity/local support.

Aotearoa New Zealand provided protection to 17 Surf Breaks of National Significance (Figure 1.2) by specifying them in the New Zealand Coastal Policy Statement 2010 (NZCPS). Compared to the approach of other countries, this provided immediate legislative protection and gave authorities a clear mandate and key role in the preservation and management of these unique and natural resources for future generations.

---

[1] http://www. surf break.org.nz
[2] https://www.savethewaves.org
[3] https://www.surfrider.org/
[4] https://www.sas.org.uk/
[5] http://www.worldsurfingreserves.org/

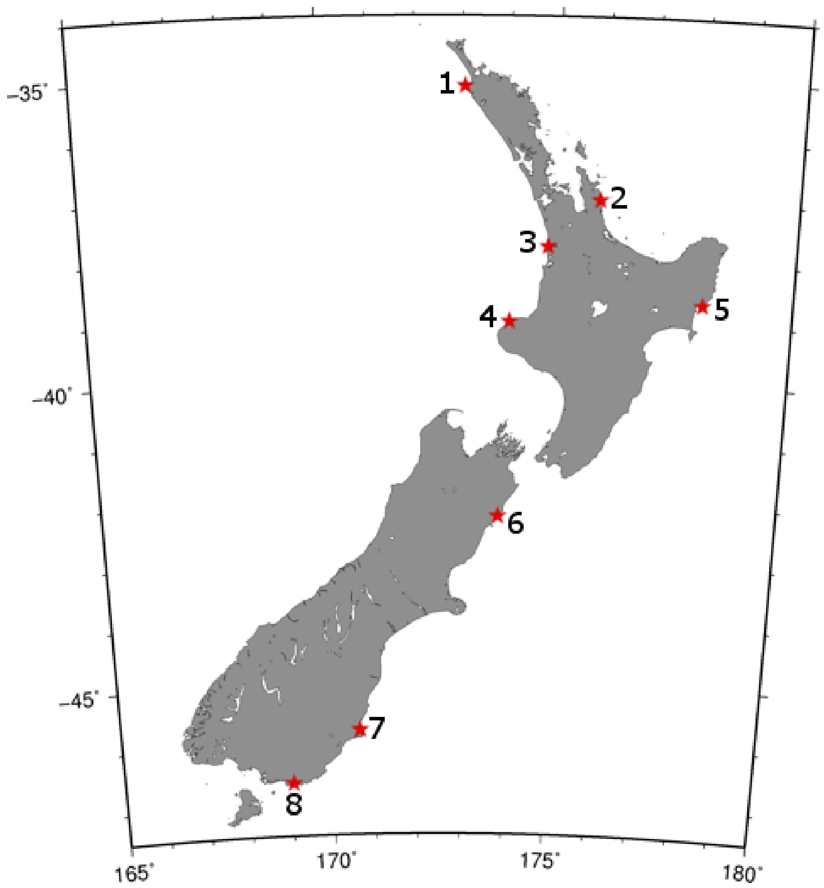


Figure 1.2: Locations of Aotearoa New Zealand's Surf Breaks of National Significance. 1) Peaks - Shipwreck Bay, and Pines – Super tubes – Mukie 2 – Mukie 1. 2) Whangamata Bar. 3) Manu Bay, Whale and Indicators. 4) Waiwhakaiho and Stent (Road – Backdoor – Farmhouse). 5) Makorori Point – Centres, Wainui (Stock Route – Pines – Whales), and The Island. 6) Mangamaunu and Meatworks. 7) The Spit (Aramoana), Karitane and Whareakeake. 8) Papatowai.

The Department of Conservation (2017a, b) undertook a review of the NZCPS and found that "*the precise identification of surf breaks of national importance has reduced disputes around their identification, raised their profile as a national resource and resulted in councils investing in facilities to support their use*". During the Board of Inquiry to develop the NZCPS it was noted that "*the economic value of surfing to tourism and the social benefits should not be underestimated*" (Board of Inquiry, 2009a, b; Department of Conservation, 2017a). Furthermore, the Board of Inquiry recorded that some of "*New Zealand's surf breaks are nationally and even internationally significant, attracting visitors from around the world, as well as providing a variety of surfing opportunities including some for learning on nursery surf breaks. The quality of the wave can potentially be compromised by developments in the swell corridor*[6,7] *seaward of the break, and the enjoyment of surf breaks by surfers compromised by*

[6] See Section 1.2 Legislative Context.
[7] Note a swell corridor is also referred to as a swell *window*, particularly outside of New Zealand.

discharges, limitations on access, and changes to natural character”. A key strength of the Aotearoa New Zealand policy is that surf breaks are delimited by the definition in the NZCPS that takes account of activities that can affect the surf break in the wider area of the swell corridor and the land-based activities in the catchment.

The NZCPS itself does not provide specific guidance on how to manage a surf break. Despite this, some regional authorities in Aotearoa New Zealand have commissioned the collation of background information on surf breaks in their regions as part of preparing specific policy provisions within their respective planning frameworks.

Skellern *et al*. (2013) observed that the constraints affecting this process include inadequate information on the resource, a lack of methodological guidance on site baseline characterisation and monitoring, and political pressure to prioritise other resource management (e.g. freshwater management and land-use). There are also constraints for community organisations who rely on volunteers and meagre financial resources to effectively engage in the process. This capacity constraint has a direct bearing on the effectiveness of the planning process, resulting in decisions often being made on a case by case basis at hearings for specific developments, which often lead to inadequate coastal management decisions (Skellern *et al*., 2013).

1.2 Legislative Context

The Resource Management Act 1991 (RMA) is the primary legislation for managing the effects of activities on Aotearoa New Zealand’s surf breaks. The NZCPS is prepared under the RMA and gives effect to the purpose of the RMA (sustainable management) for the coastal environment. Regional Policy Statements, Regional Plans, Regional Coastal Plans, District Plans and Unitary Plans each have to give effect to the NZCPS (Makgill and Rennie, 2011). If the NZCPS does not address an issue, then recourse can be made to the Purpose and Principles set out in Part 2 of the RMA. The “coastal environment" is not specifically defined in the NZCPS, but the NZCPS does provide guidance for its interpretation on a case-by-case basis. However, a constituent part of the coastal environment is the Coastal Marine Area (CMA). The RMA defines the CMA as the foreshore, seabed, and coastal water, and the air space above the water:

> (a) of which the seaward boundary is the outer limits of the territorial sea;
>
> (b) of which the landward boundary is the line of mean high-water springs, except that where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of:

i. 1 kilometre upstream from the mouth of the river; or

ii. the point upstream that is calculated by multiplying the width of the river mouth by 5.

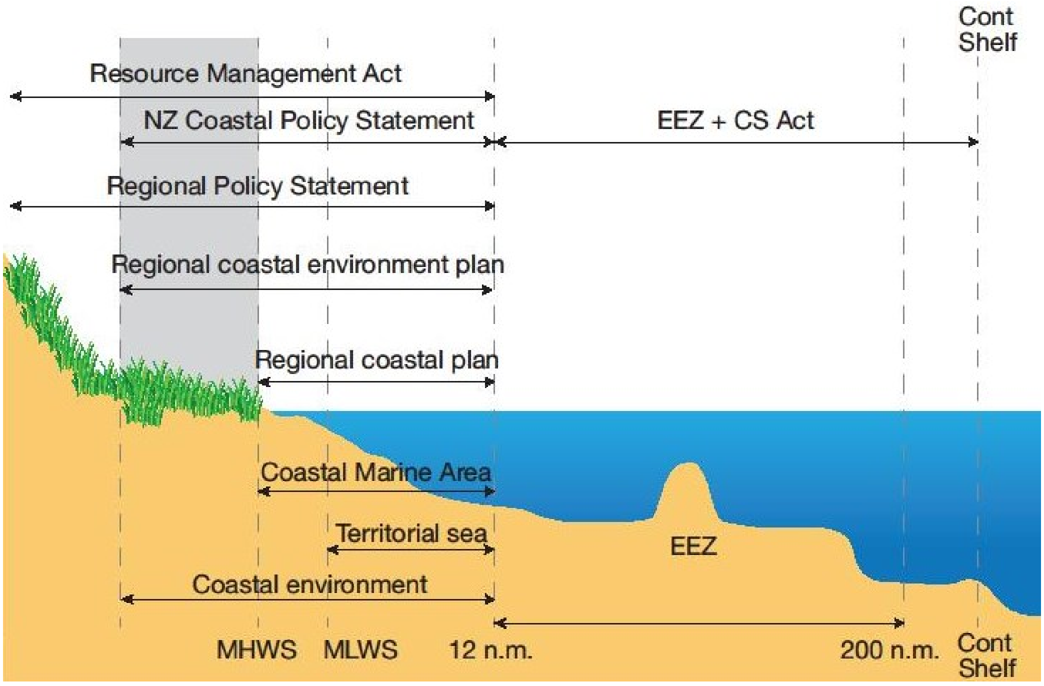


Figure 1.3: Coastal management zones in Aotearoa New Zealand. MHWS = Mean High Water Springs. MLWS = Mean Low Water Spring. EEZ = Exclusive Economic Zone. Cont Shelf = Continental Shelf. EEZ + CS Act = Exclusive Economic Zone + Continental Shelf (Economic Effects) Act 2012. N.m. = Nautical miles (image: NZCPS Guidance note).

Revision of the New Zealand Coastal Policy Statement 1994 attracted input from surfers and surfing organisations. The resulting submissions provided recommendations for the definition of a "surf break" and provisions for surf break protection (Board of Inquiry, 2009a). These recommendations were largely adopted within the NZCPS 2010 as Policy 16, which explicitly identifies the 17 Surf Breaks of National Significance in Aotearoa New Zealand, as:

Policy 16: Surf Breaks of National Significance:

Protect the surf breaks of national significance for surfing listed in Schedule 1, by:

(a) ensuring activities in the coastal environment do not adversely affect the surf breaks; and

(b) avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks.

NZCPS defines a surf break as:

> *A natural feature that is comprised of swell, currents, water levels, seabed morphology, and wind. The hydrodynamic character of the ocean (swell, currents and water levels) combines with the seabed morphology and winds to give rise to a* ***'surfable wave'****. A surf break includes the* ***'swell corridor'*** *through which the swell travels, and the morphology of the seabed of that wave corridor, through to the point where waves created by the swell dissipate and become non-surfable.* ***'Swell corridor'*** *means the region offshore of the surf breaks where ocean swell travels and transforms to a* ***'surfable wave'****.* ***'Surfable wave'*** *means a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the wave crest.*

1.2.1 Surf Breaks and Surfing Resources

While much of Aotearoa New Zealand's coastline has a wave climate conducive to surfing, not all coastlines are configured to break waves in a way conducive for surfing. Scarfe (2008) estimates that of the 18,200 km of coastline in Aotearoa New Zealand, there is, on average, one surf break every ~40 km. To exacerbate this scarcity, surf breaks can be dependent on specific wave heights, periods and direction, which may, in turn, be reliant on random or rare events such as tropical cyclones, which may also need to combine with specific tidal heights and wind directions.

Surf breaks are complex natural resources and good management decisions for surf breaks are based on a foundation of understanding. There is a body of surf science literature focused on the characteristics of surf breaks and how their dynamic nature is determined by the seabed morphology and substrate, waves, tides, wind and sediment transport (Appendix A). In addition, substantial information exists regarding the amenity and monetary value of surf breaks (Appendix B).

The most comprehensive set of research completed for physically defining surf breaks is that of Mead (2000), and the published work of Mead and Black (2001a, b, c). These works focus largely on the physical attributes, such as the types of surf break and the way in which waves break. Appendix A provides detail on surf science and the physical aspects of surf breaks. Despite the body of engineering literature available to quantitatively evaluate a surf break and breaking waves, when it comes to user enjoyment, ideal surfing conditions are diverse and subjective.

This subjectivity is not just a function of surfing ability and/or a like/dislike for a particular wave shape. There are other aspects that need to be considered when characterizing a surf break. Orchard (2017) reviewed literature related to surf break management in Aotearoa New Zealand. One of the outcomes was a framework for assessing a surf break's significance. Beyond wave breaking characteristics, it included a surf break's rarity and uniqueness, naturalness (environmental setting) and wilderness values[8], amenity values, levels of use, economic value, and historical/heritage/cultural associations.

Surfers don't just surf for 'the thrill of the ride'. The sense of freedom of riding the wave, the connection with the elemental forces of the wave, the aesthetics of the surrounding landscape, the social interactions with friends, the history of their connection to the break, and the coastal environmental quality all contribute highly to the surfing experience. As a consequence, all these factors need to be accounted for in managing the resource and threats against it.

It is the combination of physical processes (the surf break), sense and feeling, and experience that make up a **surfing resource** (Appendix B). It is therefore important to recognise the requirement to manage the resource holistically and not to treat aspects of this resource in isolation (e.g. the surf break). In this document surf breaks refer to physical feature described in the NZCPS; a surfing resource includes not only the surf break but aspects that make it a natural resource.

1.2.2 Surfing Resources and Policy

The NZCPS 2010 relates to the Resource Management Act (RMA) in that surf breaks are natural and recreational amenity resources that contribute to the natural character of the coastal environment. Access to surfing resources and their use and enjoyment are important to the social and economic well-being of people and communities, and yet they are vulnerable to adverse effects from activities in the coastal environment.

As noted above, the NZCPS covers the coastal environment which extends landward of the CMA, usually to at least the nearest ridgeline. This is to facilitate integrated coastal management across the management responsibilities of local governments responsible for preparing and administering unitary, district and regional plans covering terrestrial and freshwater areas landward of MWHS and the regional coastal plans that apply to the CMA

[8] Policy 15 of the NZCPS advises to consider aesthetic values including memorability and naturalness.

(Makgill and Rennie, 2011). The landward component of the coastal environment is essential for dealing with, amongst other things, the maintenance of water quality and access to surf breaks (Perryman and Skellern, 2011).

The landward component is an area where regional policy statements can provide guidance to district plans. Catchment planning and coastal spatial planning can assist with managing landward aspects that may affect surf breaks (e.g. dams and sand/gravel extraction that can alter sediment supplies to the coast, catchment runoff that can degrade water quality etc.), as well as in the CMA. There is clear direction in the NZCPS that such issues must be recognised:

Policy 1: Extent and characteristics of the Coastal Environment

1. *Recognise that the extent and characteristics of the coastal environment vary from region to region and locality to locality; and the issues that arise may have different effects in different localities.*
2. *Recognise that the coastal environment includes:*
    a. *the coastal marine area;*
    b. *islands within the coastal marine area;*
    c. *areas where coastal processes, influences or qualities are significant, including coastal lakes, lagoons, tidal estuaries, saltmarshes, coastal wetlands, and the margins of these;*
    d. *areas at risk from coastal hazards;*
    e. *coastal vegetation and the habitat of indigenous coastal species including migratory birds;*
    f. *elements and features that contribute to the natural character, landscape, visual qualities or amenity values;*
    g. *items of cultural and historic heritage in the coastal marine area or on the coast;*
    h. *inter-related coastal marine and terrestrial systems, including the intertidal zone; and*
    i. *physical resources and built facilities, including infrastructure, that have modified the coastal environment.*

The landward boundary of the Coastal Environment is not quantitively defined in the NZCPS, and the actual extent of the Coastal Environment has been left to authorities to define. Consideration should be given to including in the definition inland waterways and coastal hinterland, since developments in these areas can impact water quality, access to and surf break morphology.

The offshore jurisdictional range for authorities at a regional level is the edge of the territorial sea, 12 nautical miles from land. This is also the offshore boundary of the RMA; and therefore NZCPS. Activities outside the territorial sea, that fall into a surf break's swell corridor, and have the potential for adverse effects (e.g. large-scale seabed mining, petroleum recovery), are essentially beyond the influence of the NZCPS.

Policy 16 clearly identifies two major aspects as being important to the management of surf breaks, namely the physical aspects of surf break environments, and aesthetic and cultural aspects important to users of those environments. The policy does not specify that users need to be surfers; there may be other users of the water space including spectators who participate from a distance.

Policies 13 and 15 of the NZCPS provide further mandate to preserve and/or protect surf breaks. Policy 13 '*Preservation of natural character'* includes surf breaks as part of the natural character of the coastal environment, noting that *Other aspects of natural character, such as 13(2)(a) 'natural elements, processes and patterns' and 13(2)(h) 'experiential attributes, including the sounds and smell of the sea; and their context or setting'* are also relevant to surf breaks. Policy 15 '*Natural features and natural landscapes'* is also relevant, as surf breaks are specifically identifiable as natural features within the seascape.

It is clear that the relevance of the NZCPS to the management of surfing resources transcends Policy 16 and the 17 Surf Breaks of National Significance. Consideration must also be given to Policies 2, 13 and 15 of the NZCPS with regard to the surf break users and a collaborative approach, natural features that comprise surf breaks, and associated natural character. Therefore, the management of surfing resources should be considered at a national, regional and local level.

1.2.3 The Rights of Mana Whenua (local iwi)

Māori have special recognition within Aotearoa New Zealand legislature as Crown partners under the 1840 Treaty of Waitangi agreement. The Treaty of Waitangi was signed as an agreement between the Crown and Māori chiefs. At the time of signing, the Treaty ensured Māori equal participation within society, partnership in the governance of Aotearoa New Zealand, and the protection of Māori interests (Durie, 1998). By contrast, the governments subsequent policies following the signing went against those principles (Durie, 1998; Walker, 2004).

Nevertheless, the Resource Management Act 1991 recognises the Treaty of Waitangi [s8], the relationship between Iwi and water [s6(e)], and the role of kaitiakitanga [s7(a)] in managing

Aotearoa New Zealand's' natural resources (Grace, 2010). Alongside the recent Treaty settlements process, there is an increased recognition of "*Māori values as a fundamental driver for restoration as well as a basis for the ongoing involvement of Iwi in the regulation and sustainable management of natural resources*" (Grace, 2010, p. 1). Appendix C contains a link to *Mana Whakahono ā Rohe Guidance* produced by Ministry for the Environment, which details how local authorities and local iwi can work together on environmental issues under the RMA.

Within an international context, Māori rights are also recognised through the United Nations Declaration on the Rights of Indigenous Peoples 26 and 32 (The United Nations General Assembly, 2007, art. 5). Article 26 affords Indigenous peoples the right to own, use, and control their traditional lands and resources which they have traditionally owned, occupied or otherwise used or acquired, and that 'States' shall give legal recognition and protection to these lands and resources with due respect to the customs and traditions of the indigenous peoples concerned (The United Nations General Assembly, 2007). Article 32 affords Indigenous peoples the right to determine and develop priorities and strategies for the development or use of their lands and resources (The United Nations General Assembly, 2007).

Finally, Policy 2 of the NZCPS recognises that tangata whenua (local people of the land) have traditional and continuing cultural relationships with areas of the coastal environment, and that opportunities must be provided for Māori involvement in decision making and the exercising of kaitiakitanga (guardianship) over Iwi (tribal) waters.

In light of these legislative measures, the role that local Iwi provide as kaitiaki (guardians) of their rohe (region) is imperative to the management of surf breaks. Indeed, Māori and Iwi place great importance on the environmental protection of their rohe (Selby, Moore, and Mulholland, 2010). In this sense, collaborations with local Iwi can provide leverage and support throughout the process. To conclude, any engagement process with stakeholders needs to acknowledge the relationship between the Crown and Māori, by taking account of the principles of the Treaty of Waitangi, and kaitiakitanga in relation to the coastal environment and Policy 2 of the NZCPS.

1.3 Significance and Surf Breaks

The NZCPS does not provide criteria for defining what constitutes a Surf Break of National Significance, nor does it adopt any position on the stratification of surf breaks and their significance (i.e., into national, regional or local significance). The basis for the selection of 17 Surf Breaks of National Significance in the NZCPS 2010 was the Wavetrack New Zealand

Surfing Guide (Morse and Brunskill, 2004), with breaks rated 10 out of 10 on the author's 'stoke rating" being selected as nationally significant. The board of enquiry's final selection also included Papatowai and 'The Spit' at Aramoana, both with a 'stoke rating' of 8; but did not include the originally considered Wairarapa Coast surf break of 'The Spit', which rates 10 out of 10 in the Wavetrack New Zealand Surfing Guide (Morse and Brunskill, 2004). Papatowai's inclusion was the result of its growing international profile as a high-performance big wave break.

Figure 1.4: Papatowai in Aotearoa New Zealand's deep south is a Surf Break of National Significance, recognised, outside of the original assessment criteria, because of its unique characteristics as a big wave surfing venue (image: Mark Stevenson).

Stratification is a matter for councils, local Iwi and their communities to determine, and the process and terminology that have been applied to date have varied around the country. The use of "regionally" and "locally" significant is a relatively new development in terms of surfing resource management (Orchard *et al.*, 2019). This approach of stratification is consistent with planning documentation were the different authoritative levels recognise the appropriate features of significance. For example, district plans would recognise features of local significance.

When natural resources and values need protecting, they are assessed, and the level of protection is usually linked to their value. If everything is deemed significant, then the level of protection is often diluted. However, a surf break, or simply a stretch of coastline where surfing occurs, is more often than not significant to an individual, a group, or community. Comprehensive stakeholder and community engagement should be used to establish the level of significance on a case by case basis.

It is worthwhile noting that: *"It was the intention of the Board of Inquiry to the NZCPS to have an inclusive approach, in that the list is not finite, and more surf breaks may be added over time, and surf breaks are recognised as outstanding natural features in their own right (page 130 Vol 2 BOI to NZCPS) providing they meet the definition of a surf break in the glossary of the NZCPS and have been identified"*. Surf breaks of Regional Significance will likely provide candidates for nationally significant status and inclusion in Schedule 1 of the NZCPS.

1.4 Purpose of these Guidelines

Under the NZCPS, councils are tasked with considering how they will give effect to mapping and identifying natural character and natural features in regional policy statements and plans. Relevant to this and reinforcing the need for guidelines is the following statement by the Board of Inquiry for the NZCPS: "*We conclude that there should be no criteria in the policy [NZCPS 2010] for selecting further surf breaks of national significance given that there could be developments in the methodology in identifying and rating natural surf breaks*".

These guidelines were originally developed as part of an MBIE funded project (Appendix D) that aimed to build a knowledge base on surf breaks and to develop management guidelines to support the effective implementation of the NZCPS. The guidelines provide: information on the legislative and social context of surf breaks; an understanding of the physical characteristics of surf breaks and how they function; a description of factors that can compromise their amenity value; specific methodologies for management of surfing resources for authorities and consent applicants; information to assist with the identification, study, monitoring and sustainable management of surf breaks.

Coastal infrastructure (e.g. ports, erosion protection structures), the supply, transport generation and transmission of electricity, aquaculture and the extraction of minerals are activities important to the social, economic and cultural well-being of people and communities (Policy 6 NZCPS). These guidelines aim to facilitate the sustainable implementation of these requirements.

The guidelines also aim to manage the expectations of resource users and developers with respect to consent requirements where proposed activities are likely to affect access to, and the amenity value of surf breaks. The guidelines will provide stakeholders with greater clarity on how activities in the coastal environment may affect a surfing resource and the responsibilities of those undertaking the activities.

Section 2 of these guidelines provides specific direction for authorities responsible for management of surfing resources. The first set of steps are designed to support council officers identifying, mapping and characterising surf breaks in their region. Threats and risk assessment guidance is provided to facilitate prioritising resources and preparing a "watch list" of surf breaks. Guidance is given on incorporating surf break protection into policy and plans. Methodologies for baseline studies and monitoring are described.

Section 3 provides steps for resource users and consent applicants who need to assess the potential impact of a development on the amenity value of a specific surf break (s) as part of a consent application. While the starting point may be information from Council, more often than not specific studies will be required as specified in the first set of steps.

Further details relating to the steps in Sections 2 and 3 are provided in Section 4, and additional supporting documentation is available in the appendices.

Case Study: Piha's shifting sands

Image: Craig Levers

Under optimum conditions Piha Bar breaks adjacent to Taitomo Island (also called "Camel Rock" or "The Beehive") across the bay toward Lion Rock. The Inside Bar provides lefts and rights and is best surfed on an incoming tide, from mid-tide onwards. Further landward is The Ditch, a high tide "reform wave". Conjecture indicates that The Ditch no longer functions as it did in the past because of an abundance of sand in the bay.

Beach surveys that show the dunes all along the shore are growing taller and prograding seawards. Anecdotal evidence indicates that sand has infilled the Pataki Rip channel. Together these effects may have altered the circulation pattern close to shore, changed the configuration of rip channels and sand banks. The perceived result is that these changes have had a detrimental effect on the quality of the surf break.

Opinion is divided and the extent to which these effects are natural or anthropogenic are debateable. Some opinion has it that dune conservation works are the culprit. Dunes have been shaped and planted to combat coastal erosion. This has caused the dunes to prograde seawards and grow taller. It is perceived by some that while the sand is locked up in the dunes it is no longer available to build the sand banks offshore. Others would have it that the dune conservation has encouraged sand build up on the beach and in the nearshore. However, the influx of sand into the bay could also be part of a natural process. Dune progradation is occurring all along South and North Piha at decadal time scales and not just in the areas where dune conservation efforts have taken place. There is anecdotal evidence that the influx of sand into the bay is part of pulses of sand driven north along the coast by the waves, as evidenced by progradation occurring first at Karekare Beach and then at Piha.

2 Guidelines for Authorities

Use this guideline to gain a region-wide perspective and broad overview of surf breaks in a region, collect data on values and threats to prioritise efforts and resources, and identify specific measurements to make on breaks. Detailed descriptions and reasoning behind each of the following steps are provided in Section 4.

2.1 Step 1: Identify Surf Breaks

Table 2.1 shows the key steps to build a surf break database.

Table 2.1: Identification of surf breaks(See Section 4.2 for further details)

Objective: Build a database of all surf breaks		
Components		**Resources, Tools and References**
1	Review of surf/beach guides.	Bhana (1996) Morse and Brunskill (2004) Rainger (2011) NZSurf Guide (2013)
2	Stakeholder consultation through interviews and/or survey, should include: • Determination of the actual surfing area • Access points to the break • Surf break parts/sections, including common and colloquial names • Discussion around observed changes in the Coastal Environment	Peryman (2011a, b) Edwards (2012) Atkin *et al*. (2017) Reineman (2017) Orchard *et al*. (2019)
3	Map the location of the surf breaks and define a Surf Break Area (SBA). The SBA may host a single surf break or multiple surf breaks. The landward extent of the SBA can be delineated using the LINZ 1:50,000 coastline, the offshore extent where surfable waves break using a combination of knowledge gained from Components 1 and 2, maps in surf guides, satellite imagery and aerial photographs.	Components 1 and 2 Google Earth (satellite/photography) Land Information New Zealand (aerial photography) Atkin *et al*. (2015) Atkin and Mead (2017)
4	Compile the information in a database along with additional information such as photos of the break	
5	Categorise the significance of surfing resources	Orchard *et al*. (2019)

<u>Outcome and Actions</u>

- Broad understanding of surf break characteristics in the region.
- Ensure information is recorded in relevant databases.

2.2 Step 2: Construct Swell Corridors

By defining swell corridors for surf breaks an authority creates a planning tool, similar to coastal hazard mapping. A swell corridor dataset can aid the decision-making process and be used to identify sites where activities such as aquaculture, dredge spoil disposal and wave energy infrastructure could block or modify waves travelling through the swell corridor. Table 2.2 shows the key steps to determine swell corridors.

Table 2.2: Construct swell corridors (See Section 4.3 for further details).

Objective: Construct Swell Corridors.		
Components		**Resources, Tools and References**
1	Define swell corridors and buffer zones. Undertake numerical modelling of the offshore region to determine the area offshore of a surf break where ocean swells travel and transform into surfable waves.	Atkin *et al*. (2015) Atkin and Mead (2017) Atkin and Greer (2019)
2	Compile the information in a GIS database and make available to public.	Geographical Information Systems Google Earth

Outcome and Actions

- Swell corridors are delineated for surf breaks in the region.
- Ensure information is recorded in relevant databases.

2.3 Step 3: Threats and Risk Assessment

Table 2.3 shows the key steps in undertaking a risk assessment. Table 2.4 categorises activities and threats according to their source; whether they originate in the catchment and connecting waterways (rivers or estuaries), in the vicinity of the surf break itself, offshore from the break in the swell corridor, from natural events or social/cultural/technological change. It also provides examples from Aotearoa New Zealand and overseas where surf breaks have been affected and/or been assessed. This lists of activities and impacts are not definitive. Table 2.5 through to Table 2.8 can be used to determine a surf break risk rating.

Activities and threats range in scale from local to global and are location dependent. They have different time frames, the effects can be permanent or temporary, and while some effects can be mitigated, many cannot. They can have negative and positive effects on wave quality and the surf break environment - while some engineering works can have a positive effect on surf breaks (by design or accident) the effects can also be negative. Some threats are more common at specific geomorphic types of surf breaks (e.g. channel dredging, issues with boat traffic, and water quality are more common to river/estuary bar breaks).

Threats to surf breaks may also be threats to Māori and Iwi interests in the environment and their role in exercising kaitiakitanga. In this respect the interests of surfers align closely with Māori conservation views (refer to Selby, Moore, and Mulholland, 2010).

The value of a risk assessment is that it allows authorities to develop a "watch list". The watch list facilitates decision making and assists with prioritisation of resources for activities such as monitoring (Section 2.5) and the allocation of resources. Any surf break, surfing resource or SBA receiving a risk rating of extreme (Table 2.8Table 2.8) requires immediate action and resources should be directed to enabling Baseline Studies (Section 2.5) if not already undertaken; and, Baseline Monitoring (Section 2.6) should be initiated immediately should the consequence be major or catastrophic (Table 2.6).

Table 2.3: Surfing resource threats and risks(See Section 4.4 for further details).

Objective: Threats and Risk Assessment		
Components		**Resources, Tools and References**
1	For each surfing resource compile known facts and issues	Section 2.1 e.g., Table 2.4
2	Score surf break area on sensitivity and vulnerability	Table 2.5 Appendix A Appendix B
3	For each surf break, determine consequence for each activity/process	Table 2.6
4	For each surf break, determine likelihood of impact each activity/process	Table 2.7 Section 4 discussion/case studies
5	For each surf break, determine risk rating for each activity/process	Table 2.8
6	Prioritise surfing resources based on risk rating	
7	Initiate baseline characterisation and monitoring for top priority locations	Section 2.5 Section 2.6 Atkin *et al.* (2017)

<u>Outcome and Actions</u>

- Establish risk rating for each activity for each surf break.

Table 2.4: Various activities that pose a threat to surf break amenity. The list is not definitive.

Activity, Threat and/or Source	Potential Effects on Surfing Resources	Examples/References	Potential Mitigation Options
Hinterland, Catchment and Waterways			
Forestry	Sediment runoff into waterways creating sediment plumes in the CMA and reducing water quality in an SBA. Increased number of felled trees and branches in an SBA poses a health and safety risk to users. Additional sediment may benefit some surf breaks. Discolouration of waters following rain events. Impacts on the natural setting/ wilderness experience, and also impacts on ecological aspects at a surf break.	Resource Management (National Environmental Standards for Plantation Forestry) Regulations 2017	Manage stormwater, sediment and wood debris runoff using forestry industry best practice techniques.
Quarrying	Water quality issues as above.		Suitable silt and stormwater management, including the application of sediment ponds
Material extraction in waterways (e.g., dredging)	Sediment plumes in waterways delivered to SBA. Changes to sediment transport pathways.	Whangamata Bar, NZ Matakana Island, NZ	Best practice management should be applied, including measures such as silt curtains and bunding, and extraction methods such as cutter-suction that reduce sediment plumes into the surrounding waters.
Port and marina construction, development and maintenance	Alterations to tidal prism can change hydrodynamics and, subsequently sediment transport regime, and morphology. Direct and indirect alterations to refraction patterns. Delta breaks particularly susceptible. Increased vessel activity: vessel wakes reduce wave quality; sharing of space and access points. Requirement for dredging activities (see Dredging). Water quality issues associated with marina and increased boat activity. Noise associated with construction activities.	Whangamata Bar, NZ (Atkin *et al*., 2017) Mundaka, Spain (Liria *et al*., 2009)	Undertake field and modelling studies to predict effects of the developments and modify design to minimise impacts. Determine baseline conditions and monitor changes. Enforce speed limits for vessels using entrance channels. Educate users on sharing space.

Restriction of access by landowners	No access through private agricultural land. Industrial and residential developments in the CMA.	Whiterock, NZ Broad Bench, UK The Ranch, USA	Negotiate access as mitigation and condition of consent.
Runoff from rural and urban point and diffuse sources	Runoff contaminated with animal waste from farms; and discharges for outfalls, drains and septic tanks give rise to water quality issues. Can result in increased algal growth on rocky shore presenting a slip hazard to users of an SBA.	Manu Bay/Whale Bay (Atkin *et al*., 2017)	Manage runoff at source. Follow Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment, 2002).
Transgressive dune field: Planting or development.	Inhibits delivery of material to an SBA either directly, or indirectly to the local sediment cell.	Shipwreck Bay, NZ St Francis Bay, South Africa	Undertake studies to determine whether sand supply is important to surf break functionality and manage planting accordingly.
In and around an SBA			
Beach nourishment	Changes in seabed morphology. Alters existing sediment budget. Effects can be positive or negative. Beach can overfill with sediment. Short-term water quality issues. Short-term access restrictions to SBA during works.	Gold Coast, Aus. Benedet *et al*. (2007) Dally and Osiecki (2018)	Undertake field investigations and modelling of coastal processes and iterate with proposed fill volumes and placement to produce desired outcome.
Construction of jetties, groynes, breakwaters, boat ramps and other hard structures in the nearshore	Structure can change the seabed directly and/or coastal processes. Significant knock-on effects. Changes in wave quality can be both positive and negative. Complete or partial occupation of the SBA. Water quality issues during construction. Loss of natural character and change in landscape.	Manu Bay, NZ Ti Point, NZ Bastion Point, Aus. Kirra Point, Aus. Scarfe *et al*. (2003)	Undertake field investigations and modelling of coastal processes and iterate with proposed structure designs to minimise effects.
Dune planting programs	Reduced access by fencing off areas of the dune/beach. Building up the height and volume of the dunes restricts views. Limits cross shore exchange.	Piha, NZ (Dahm, 2013) North Narrabeen, New South Wales, Aus.	Provide walkway access to beach. Set limits on height of dunes. Promote native dune species.

Nearshore dredge operations	Removes sand directly from the nearshore bars and leaves (temporary) pits in the seabed. May alter wave refraction.	Pakiri, NZ Hilton (1989)	Undertake field investigations and modelling of coastal processes to predict and quantify effects to inform decision making.
Reclamation	See construction of jetties, groynes, breakwaters, boat ramps and other hard structures in the nearshore.	Wellington Airport Extension, NZ Mangamaunu Point, NZ Kuta Beach, Indonesia	See construction of jetties, groynes etc.
Recreational fishing	Conflicts between users sharing space, access, and occupation of specific areas. Entanglement of surfers in lines and tackle from boat and beach fishers, including remotely operated fishing devices (e.g., Kontiki). Burley can attract dangerous marine animals (e.g. sharks). Vehicular traffic on beach.	Manu Bay, NZ Whangamata Bar, NZ Atkin *et al*. (2017)	Educational signage at access points to beach.
River/Stream training	Changing or fixing the location of beach streams which naturally meander back and forth along the shore and along the beach may reduce the complexity of the nearshore. Can result in less ephemeral features and the creation of new established surf breaks.	Piha, Auckland, NZ Dahm (2013)	Undertake investigations of coastal processes to predict effects and inform decision making.
Shoreline armouring	See construction of jetties, groynes, breakwaters, boat ramps and other hard structures in the nearshore. Major effect from reflection of wave energy on both beach erosion (accelerated) and surfing wave quality.	St Clair, NZ	See construction of jetties, groynes etc.
Nearshore, Offshore and Swell Corridor			

Aquaculture	Wave are attenuated when passing through structures. Reductions in wave height and possible changes to wave direction. Can affect wave quality directly by modification to incident wave climate; and indirectly by altering existing coastal processes and sediment transport regime, resulting in change to the seabed. Increase in dangerous animals (e.g., sharks). Direct or partial occupation of SBA. Water quality issues. Access limitations.	Martha Lavinia, Aus. Taylor and Dempster (2016) Plew (2005)	Field investigations and modelling of coastal processes and iterate with options for farm structure in the model to minimise effects.
Dredging of port/harbours approach channels	Modification to incident waves. Sediment trap reducing littoral transport. Altered seabed configuration. Water quality.	Port of Tauranga, NZ Port of Napier, NZ Centreport, NZ	Field investigations and numerical modelling of coastal processes and iterate with options for channel alignment/depth/width/length in the model to minimise effects.
Dredge spoil disposal	Mounds on the seabed affect waves by refraction, diffraction and shoaling. Altered seabed configuration: impacts on incident wave conditions; impacts on SBA morphology; over filling of beaches; erosion if not placed correctly. Water quality. See Beach nourishment. Can result in positive impacts.	Aramoana, NZ Whareakeake, NZ Main Beach, NZ Superbank, Aus. Cronulla, Aus. (Pitt, 2009; 2010)	Field investigations and modelling of coastal processes and iterate with various option for mound dimensions and location to minimise effects at the SBA.
Large scale seabed mining	Pits and mounds in/on the seabed affect waves by refraction/diffraction Can result in changes to surfing wave quality either directly by modifying wave climate or indirectly through changes to sediment transport. Water quality issues.	South Taranaki Bight, NZ (Hume et., 2013; Mead, 2013)	Field investigations and modelling of coastal processes and iterate with various option for pit/mound dimensions and location to minimise effects at the SBA.
Oil Spills	Health and safety risk.	Rena Incident (New Zealand Coastal Society, 2014)	Follow oil spill prevention standards.

		New Zealand Marine Oil Spill Readiness and Response Strategy 2018-2022	
Wind or wave energy arrays	See Aquaculture. Potential to affect multiple surf breaks.	The Wave Hub, UK (Black, 2007) Port Fairy, Aus. (Flocard and Hoeke, 2017)	Field investigations and modelling of coastal processes and iterate with options for array structure in the model to minimise effects.
Social and technological			
Beach closure for events	Temporary occupation of SBA and nearshore (e.g., SLSNZ events, Surf Competitions, Training, Memorials, Festivals etc.). Competition for space. Exclusion from SBA to those not part of the event- raises "right to surf" conflicts. Water quality and littering issues associated with event.		Notify events well in advance via news channels and social media. Organised clean up after events.
Different surfing abilities	Learner surfers pose a significant health and safety issue due to a lack of experience and control. This is critical at more challenging surf breaks where an inexperienced surfer can be quickly out of their depth. Common occurrences are related to positioning and users getting in each other's way, the inability to control equipment especially around take off zones and when duck diving waves. Advanced surfers taking all the waves.	www.aotearoasurf.co.nz	Educate users about surfing etiquette: how to behave in the surf. Signage and education to push learners to safer areas.
Different surfing (water) craft	Shortboards, longboards, body boards, foil boards, Stand Up Paddleboards (SUPs), kite surfers, sail boarders, kayaks, surf/wave skis, body surfers all compete for water space and waves. Can result conflicts between users and injury.	Smallman (2018)	Educate users about surfing etiquette: how to behave in the surf.

Improved equipment	Improved wetsuits allow surfers to remain in the water for longer meaning less turnover of users and more users in the water at one time. New craft for wave riding being developed.	Bourne and Ponting (2017)	Bylaws and designating areas (e.g. specific areas for foil boards).
Improved facilities, infrastructure and access	Paved roads to sites lead to more users. New or improved facilities onshore (e.g. parking and toilets) make the experience more user friendly. More accessible air travel. The result may be overcrowding. Increased usage of surf breaks and the potential for conflicts at popular spots.	Manu Bay, NZ Seal Rocks, Aus.	Educating users about surfing etiquette.
Increasing surfer population	Overcrowding. Environmental damage through litter and damage to intertidal habitat. Potential for conflicts at popular spots.	Bourne and Ponting (2017)	Provision of facilities for parking, rubbish disposal, and camping. Signage and clearly delineated access routes.
Management requirements	Potentially exposes Surf Breaks of Local Significance and secret spots.	Atkin (2017) Orchard *et al*. (2019)	Designate broad areas without specifying particular breaks (e.g., Known Surfing Areas).
Overcrowding	Puts pressure on lesser-known surf breaks. Leads to conflict between users. Pressure on existing facilities.	Bourne and Ponting (2017)	Improve facilities and signage educating users about surfing etiquette.
Surf forecasts and knowledge	Improved ability to predict good surfing conditions results in overcrowding when conditions are good; potential for conflicts at popular spots.	Mach *et al.* (2018)	
Surf tourism	See Improved facilities, infrastructure and access. Overcrowding.	Bourne and Ponting (2017)	
Use of SBA beyond surfing	See Recreational Fishing. Beach closure for (non-surfing) events.		Bylaws and dedicated areas (e.g., Ski lanes).

Table 2.5: Surf Break Sensitivity Rating. It is commonplace in the marine environment for the seabed to be made of a range of particle sizes. These guidelines have not considered mud bottom breaks.

	Potential Break Type	General Material Size	Wave Quality Reliance on Sediment Transport Regime
1	Rock Ledge; Reef	Consolidated Rock	Low
2	Reef; Point		
3	Point; Beach; Delta		
4	Beach; Delta		
5	Delta	Fine Sand	High

Table 2.6: Consequence of activity

Consequence of activity	Category	Definition	Example
Catastrophic	1	Permanent/irreparable damage to/loss of the whole surf break(s)	Occupation of SBA Major reclamation Port construction
Major	2	Activity permanently effects access to and/or enjoyment of a surfing resource; and/or activity results in on-going health and safety issues; and/or potential for physical changes to a large part of the SBA; and/or a permanent change to the natural character, aesthetic or wilderness attributes of the surfing resource.	Complete loss of access to break (except by sea) Reduced ride length. Reduced wave quality. Wastewater outfall Coastal protection works. Coastal landscape altered by coastal development
Significant	3	Activity temporally effects, for sustained periods of time, access to and/or enjoyment of a surfing resource; and/or activity results in health and safety issues. No physical impacts	Turbid water Contamination Regulated access. Ski-lane
Minor	4	Activity temporally effects access and/or enjoyment to a surfing resource for relatively short periods of time (e.g. <24 hours). No physical impacts	Beach closure for sporting events/surf carnival

Table 2.7: Likelihood of impact

Likelihood of impact	Category	Definition
Very Likely (Permanent/ Frequent)	A	Will obviously occur frequently and/or permanently, activity being undertaken in SBA; examples exist of impact; and/or a sensitivity rating: 5
Likely (Frequent)	B	Potential for activity to occur frequently, activity being undertaken in or near to SBA; and/or similar examples exist; and/or sensitivity rating: 3-4
Moderate (Occasional)	C	Potential for activity to occur, activity being undertaken near to SBA or within catchment; and/or examples exist; and/or sensitivity rating: 2-3
Unlikely (Remote)	D	Activity unlikely to occur, activity being undertaken outside of catchment and/or embayment; no examples exist; and/or sensitivity rating: 1-2
Highly Unlikely (Rare)	E	Activity highly unlikely to occur, activity being undertaken outside of catchment and/or swell corridor no examples exist; and/or sensitivity rating: 1

Table 2.8: Risk Rating

Risk Rating Table					
		Catastrophic-1	Major-2	Significant-3	Minor-4
Very Likely	A	Extreme	Extreme	Extreme	High
Likely	B	Extreme	Extreme	High	Moderate
Moderate	C	Extreme	Extreme	High	Low
Unlikely	D	Extreme	High	Moderate	Low
Highly Unlikely	E	High	High	Moderate	Low

2.4 Step 4: Surfing Resources in Policy and Plans

To effectively manage surfing resources, they must be incorporated into the appropriate legal and planning frameworks.

Table 2.9: Incorporating surfing resources into council planning documents (See Section 4.5 for further details).

<table>
<tr><th colspan="3">Objective: Incorporate surfing resource policy into the relevant parts of regional policy statements, coastal plans and regional coastal plan</th></tr>
<tr><th colspan="2">Components</th><th>Resources, Tools and References</th></tr>
<tr><td>1</td><td>Draft provisions for policy and plans that relate to:
o Nationally, regionally and locally significant surf breaks (as required)
o Outstanding natural character or high natural character
o Natural landforms in the coastal environment</td><td rowspan="2">Resource Management Act:
• Section 5; Section 6; Section 7
NZCPS 2010:
• Policy 2; Policy 6; Policy 13; Policy 15; Policy 16
Taranaki Regional Council (2016)
Auckland Council (2018)</td></tr>
<tr><td>2</td><td>Draft provisions for policy and plans regarding activities in the coastal environment relevant to surfing resources.</td></tr>
<tr><td>3</td><td>Have policy reviewed (include local Iwi) with an aim for inclusion in the next revision of plan/policy/document.</td><td></td></tr>
</table>

2.5 Step 5: Baseline Studies

Optimise the use of limited resources by undertaking studies/measurements at high priority sites. Activities that have the potential to impact on surf breaks will require monitoring conditions as part of the resource consent(s). See Appendix E for further details on surf break conditions and monitoring.

Table 2.10: Baseline monitoring (See Section 4.6 for further details).

Objective:		
Components		**Resources, Tools and References**
1	Select high priority sites for baseline studies based on risk rating, incorporate into annual and long-term plans.	Steps 1 to 3 above
2	Select monitoring methodology based on the potential threats.	See Appendix E Technical experts
3	Initiate monitoring as soon as possible in order to collate enough baseline data to characterise the surf break and determine natural variation.	
4	Compile the information in a database and make publicly available.	Geographical Information Systems Online data portals

<u>Outcome and Actions</u>

- Baseline monitoring established for priority surf breaks in the region.
- Ensure a suitable and safe data archive is being used to secure baseline monitoring data.
- Note, other than ensuring that the monitoring data is fit for purpose, data analysis can be undertaken at any stage in the process (e.g. at a later stage when funding is available; by an independent consultant for surf break characterisation to support a resource consent). However, the suitability of a data collection programme is often best determined once data is analysed; therefore, early implementation of monitoring is extremely beneficial.

2.6 Step 6: Monitoring to Assess Change

To determine change occurring at a surf break (whether through natural processes or human-induced) there needs to be continuity in monitoring (Section 2.5) so that new data can be compared to baseline data. Data sets need to be sufficient so that short-term change, long-term change and natural variability can be identified.

Table 2.11: Monitoring change at a surf break (See Section 4.6 for further details).

Objective:		
Components		**Resources, Tools and References**
1	Select monitoring methodology based on the potential threats and the baseline monitoring data.	Appendix A Appendix E Technical experts
2	Analyse baseline data to characterise the surf break(s) and/or other associated variables (e.g., water quality, wave height attenuation)	
3	Analyse the monitoring data using the same methodologies as applied to the baseline data	
4	Compare the monitoring data to the baseline data to assess change	
5	Response to measured change. If change is detected, then the first consideration is whether or not the change is natural or human-induced.	See Appendix E Resource Consent Conditions Adaptive management Abatement orders

Outcome and Actions

- A monitoring database
- Secure monitoring data

Case Study: Shellfish and surf breaks

The Firth of Thames has a series of surf breaks that work during both short period wind-generated swell and longer period tropical cyclone swells. These breaks are unique in that they work when very few other breaks are surfable and are close to the growing Auckland population. Due to the steep gravel nature of the seabed at most of these surf breaks, the short-period waves can break with high intensity. Large aquaculture farms within the swell corridors of these breaks have the potential to negatively impact on these breaks by reducing wave heights. There is little understanding of wave transmission and attenuation through mussel farms. Given the uncertainty of the impacts on these surf breaks, appropriately design monitoring of wave attenuation and adaptive management strategies need to be applied. For instance, appropriate conditions of consent will need to consider wave measurements offshore and inshore of the proposed 460 ha mussel farm, before and after it is put in place in order to determine impacts on wave heights. Impacts could be managed through adaptive management such as managing stocking densities on the mussel droplines, which influences the level of wave attenuation.

Image: Marlborough District Council

3 Guidelines for Resource Users and Consent Applicants

This section of the guidelines aims to provide instruction on surf break characterisation and impact assessment to those who wish to undertake resource use and development activities within the CMA, inland waterways, catchment and coastal hinterland that may impact on a surf break(s).

The studies required to ensure sustainable management practice will depend on the site characteristics and nature of any activity. The steps prescribe in this section are broadly similar to that outlined in Section 2. However, a more in depth and site-specific understanding of the surf break's characteristics is required in order to assess potential and actual impacts and determine any requirements for conditions if necessary.

As described in Section 1.2, there are several aspects of surf breaks and surfing resources that are relevant to the RMA and the NZPCS, as well as regional and district plans, and these aspects require varying levels of protection from activities that may impact on them. This means that surf breaks must be considered in the Assessment of Environmental Effects (AEE) for resource consent applications.

Case Study: The Bar Saga

Whangamata Bar lies at the entrance to Whangamata Estuary and is one of 17 Surf Breaks of National Significance. There is ongoing debate as to whether the quality of the surf break has been compromised by anthropogenic activities, in particular the maintenance dredging programme for the entrance channel to the marina inside the harbour.

Image: J. Milek

Construction of the marina began in September 2008 and was completed by October 2009. Access to the marina along the channel required dredging of approximately 32,000 m^3 of material. Periodic maintenance dredging is employed to ensure the channel retains a depth of ~1.5 m below Lowest Astronomical Tide. Initial dredging was set at 2,000 to 3,000m^3 per annum, but has risen and in 2010 was consented at 10,000 m^3. While there are morphological differences in the bar's overall shape pre- and post-marina development, due to a lack of appropriate monitoring data it is debatable as to whether these differences are natural or in any way connected to the marina development. In 2012 the Surfbreak Protection Society (SPS) presented a report to the Hauraki Gulf Forum which triggered a review of the maintenance dredging consents. The review initiated a 4-year photographic study from 2013-2017 which SPS believe shows a direct link between dredging activity and morphological change in configurations of the flood and ebb tidal deltas and the tidal inlet throat which directly affect surf quality.

3.1 Identification of Surf Breaks, Swell Corridors and Threat/Risk Assessment

Table 3.1 provides key steps to assistant in resource consent applications.

Table 3.1. Identification of surf breaks, swell corridors and threat/risk assessment

Objective: Consent Application Requirements		
Components		**Resources, Tools and References**
1	Check with consenting authority for existing resources relevant to surf break management.	Regional, district and unitary authorities Department on Conversation www.surfbreakdata.org See Section 2 2.1
2	Identify surf breaks that may be affected by the proposed activity(s).	Technical expert
3	Complete any components in Steps 1 to 3 (Section 2) that have-not already been undertaken by consenting authorities relevant to the surfing resources in question.	See Section 2
4	Undertake a thorough literature review for relevant cases to determine actual and potential impacts	Technical expert
5	Engage a specialist in surfing resources to assist in completing the requirements of the resource application and provide relevant information for stakeholder engagement.	Technical expert
6	Stakeholder engagement – engage with stakeholders (including, but not limited to, local Iwi, surfers, resource managers, local businesses, etc.) as early as possible in the process. Collect data on attribute values of surfing resources.	Section 4.1 Appendix B Appendix C Orchard *et al*. (2019)
7	Cultural Impact Assessment	Section 4.5 Appendix C
8	Undertake an Assessment of Environmental Effects concerning the surfing resource(s).	Appendix E
9	Consider the actual and potential impacts identified in the AEE and propose, mitigation measures, conditions that include monitoring and how adaptive management will be implemented.	Appendix E

3.2 Detailed Characterisation

Detailed characterisation is not only required to gain a high-level understanding of the mechanics of a surf break, but to determine criteria/thresholds levels with respect to conditions of resource consents. Detailed characterization will require technical input from and expert. Detailed characterization and monitoring are intrinsically linked (Section 2, Step 5 and Step 6); monitoring to some degree has to be undertaken to develop detailed characterization; the learnings from which will likely inform further monitoring.

These recommendations are an extension of Section 2: Guidelines for Authorities; however, it is likely that the methods presented in this section are, or will initially, be applied to specific surfing resources.

Table 3.2: Detailed characterisation

Objective: Detailed Characterisation of Surf Breaks		
Components		**Resources, Tools and References**
1	Up to date surfer knowledge transfer.	Stakeholder engagement Section 4.1
2	Initiate monitoring and data collection as soon as possible.	Scope as per Section 2.5 – baseline studies
3	Undertake detailed desktop assessment.	literature review and historical shoreline change www.surfbreakdata.org
4	Analysis of collected data.	Technical expert
5	Establish calibrated numerical model(s).	
6	Construct calibrated swell corridor.	Atkin and Greer (2019)
7	Determine wave breaking characteristics.	Appendix A Technical expert
8	Determine surf break formation and maintenance mechanisms.	

Should the resource consent be granted which has the potential to impact on a surf break(s), then appropriate consent conditions will be specified (see Appendix E – Conditions for Resource Consents). Such conditions will include monitoring to assess change (as set out in Section 2.6 above), and adaptive management provisions to avoid, remedy or mitigate any impacts detected by monitoring.

4 Additional Information for Users

This section provides further detail and discussion around each of the guideline steps/components provided in Sections 2 and 3.

4.1 Stakeholder Engagement

Any required stakeholder engagement should include local Iwi, surfers, authorities, local businesses, residents and property owners. Appendix C details considerations and provides useful resources for engagement with Mana Whenua.

Stakeholder meetings/workshops should be undertaken early in the process to both inform stakeholders and gain a thorough understanding of surf break characteristics. Information such as the area(s) being used, usage/frequency, values and other information pertaining to the form and function of the surf break(s) should be recorded as minutes and provided back to stakeholders for comment, which will, more often than not, provide a greater level of detail. These meetings/workshops provide an opportunity to discuss elements relevant to a CIA (Section 4.5).

Figure 4.1: Stakeholder consultation is critical to the successful development of surf break management strategies. Aerial photos annotated with information about surf break characteristics, usage, threats and coastal processes are useful tools to inspire and focus discussion.

4.2 Identification of Surf Breaks

City, district and regional councils, and unitary authorities are collectively responsible for the management of Aotearoa New Zealand's waterways, catchments, coastal hinterland and CMA. The responsibilities of these authorities in regard to surfing resources is twofold. Firstly, there are ongoing obligations to resource management under the NZCPS and associated unitary, regional and district plans. Secondly, authorities, to varying extents, are responsible for and/or involved in, the consenting of activities.

A consistent theme in Policies 13 and 15 of the NZCPS is the identification assessment of natural features and natural landscapes of the coastal environment with particular regard to "*natural science factors, including geological, topographical, ecological and dynamic components*" (Policy 15).

There is a wealth of information available online and in published literature regarding surfing locations. Surf and beach guides are a good starting point (e.g. Bhana, 1996; Morse and Brunskill, 2004; Rainger, 2011; NZSurf Guide, 2013 etc.). However, these guides may not provide information on all surfing resources within a particular area.

Surfers, especially those that are local to and/or have a history with a particular area of surfing can acquire in depth knowledge about the coastal environment and about wave resources in particular (Reineman, 2017). Engagement with such stakeholders is imperative to identifying surf breaks and understanding value attributes (Orchard *et al*., 2019). Undertaking surveys (in person, online) or workshops is very valuable in extracting surf break information from the surfing community (Peryman, 2011a, b; Atkin *et al*., 2017; Reineman, 2017). Organisations such as Boardriders Clubs, Surf Life Saving NZ (SLSNZ), Surfing NZ and the Surfbreak Protection Society (SPS) are ideal starting points. However, it should be noted that these organisations are not representative of the whole surfing community and many local surfers may not be affiliated. Therefore, additional effort is required to engagement with the wider surfing community, such as the use of surveys, publicly advertised workshops, and snow-ball sampling strategies whereby stakeholders identify other potential participants for engagement (Salganik and Heckathorn 2004).

During the Department of Conservation's *Review of the effect of the NZCPS 2010 on RMA decision-making* (Department of Conservation, 2017a, b), it was noted to the review group by the surfing community that some surf breaks around Aotearoa New Zealand are more significant than those listed in Schedule 1 of the NZCPS; and that there is a reluctance to identify surf breaks as this would expose them to a larger group of users.

The general inclination of surfers to keep the number of participants at a surf break to a minimum is a ubiquitous issue in surfing resource management. "Secret Spots" are perceived as being known to a few, closely guarded and/or challenging to access (Orchard *et al*., 2019). Following the identification of surf breaks that fall in to the "secret spot" category, Atkin and Mead (2017) recommended, with a view to avoiding discord within the surfing community by exposing specific surfing locations, identifying Known Surfing Coastlines (KSCs), were surf breaks along these coastlines could fall under the title of Surf Breaks of Local Significance (SBLS). This approach is ambiguous and non-descript, with the aim of concealing specific details regarding the surf breaks and maintaining their "secret" status. At the same time this method bookmarks their existence should management decisions concerning a section of coast be required (Atkin, 2017). Orchard *et al*. (2019) have likened the approach of Atkin (2017; after Atkin and Mead, 2017) to the 'silent file' approach used by Ngāi Tahu for culturally sensitive sites that tangata whenua do not want publicly disclosed (Tau *et al*., 1990).

Delineation between varying levels of significance and priorities is a strategy often favoured by authorities as it assists with prioritisation of resources. Whilst the NZCPS 2010 does not provide a specific mandate to identify regional and local surf breaks within Policy 16, other policies (13, 15) certainly foster such an approach. Categorising surf breaks as nationally, regionally or locally significant, as well as identifying 'nursery breaks' was discussed in the Board of Enquiry (2008a, b) for the development of the Proposed NZCPS 2010; and is reviewed in Orchard *et al*. (2019).

Taranaki Regional Council are the only authority to have defined Aotearoa New Zealand's first 'Nationally Significant Surfing Area' (Taranaki Regional Council, 2016; Orchard, 2017). This approach is a sizable step up from the regionally significant Surf Break Areas of Atkin *et al*. (2015) and Atkin and Mead (2017) that hosted multiple surf breaks and recognized that the wider area of surf breaks holds significant economic, social and amenity value. Furthermore, it is a step towards a national surfing reserve as developed in Australia (Farmer and Short, 2007) and the World Surfing Reserves (Skellen *et al*., 2009; 2013; Short and Farmer, 2012) that are being accredited globally.

The approach taken by authorities in delineating surf breaks, if any, should be undertaken on a case by case basis. The delineation of surf breaks at national, regional and local levels is viewed by some stakeholders as inappropriate. The concern being that the locally significant bracket may offer less protection in policies and plans. An assessment needs to reflect on the attributes of a surfing resource discussed in Orchard *et al*. (2019) (see Section 1.2.1; Appendix B); and also consider the most sustainable way of managing surfing resources.

4.3 Swell Corridors

A swell corridor is defined in the NZCPS as "*the region offshore of a surf break where ocean swell travels and transforms to a 'surfable wave*". A swell corridor is essentially an offshore extension of a Surf Break Area (Atkin and Greer, 2019).

To date, determination of swell corridors has been a numerical modelling exercise (Figure 4.2), with the aim of creating a spatial dataset to aid in the management of surf breaks. A swell corridors data base provides a useful planning tool for authorities when considering the potential impacts of activities in the CMA. The process is similar to regional scale coastal hazard zoning, in that this information can be applied as the first order assessment, and a more in depth, site-specific assessment should be undertaken during any resource consenting process.

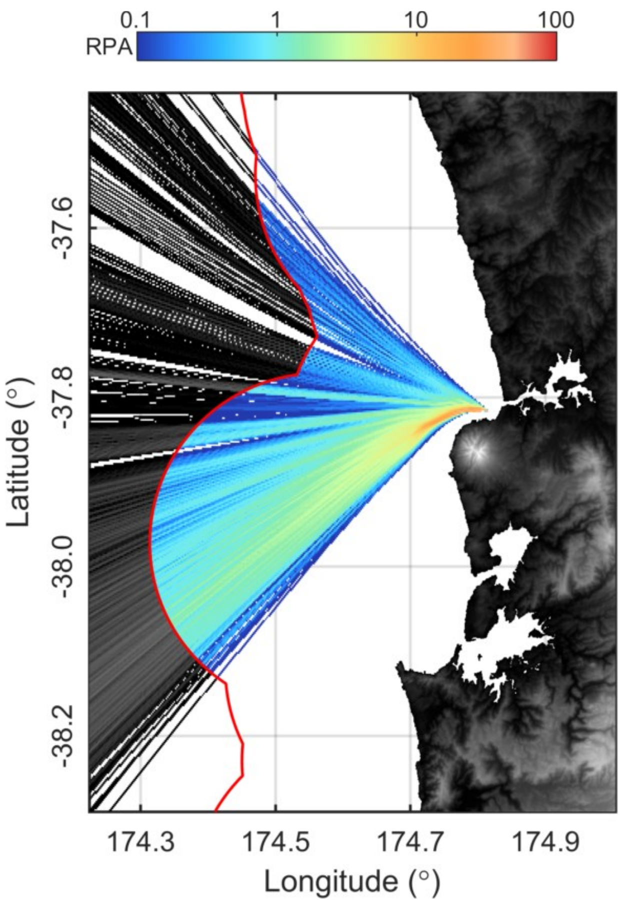


Figure 4.2: Swell corridor presented as Relative Percent Activity (RPA) determined by streamlines from numerical model output for Manu Bay. Data outside the territorial sea (red line) is shown in greyscale (Atkin and Greer, 2019).

In developing a first order assessment tool for Surf Breaks of Regional Significance in the Waikato (e.g. Figure 4.3), Atkin and Mead (2017; after Atkin *et al*., 2015) used an uncalibrated numerical modelling framework. In the case of Atkin and Mead (2017) the extent of the swell corridor and adjacent buffer zone were determined based on percentage occurrence of a particular wave condition. Buffer zones were included for the following reasons (in no particular order): to account for Policy 3 of the NZCPS: A precautionary approach; while numerical modelling is an appropriate tool for studies such as this, the model used here has not been calibrated; numerical modelling is always limited by some form of grid resolution; and, any developments proximal to an established SBA have the potential to affect wave conditions within that SBA (e.g. a seawall adjacent to, but not inside an SBA may cause wave reflections and alterations to wave breaking properties within the SBA). Atkin and Greer (2019) present and discuss different methodologies for constructing swell corridors. For a detailed assessment they use a Relative Percentage Activity (RPA) that considers the contribution of different areas to surfable conditions for a surf break.

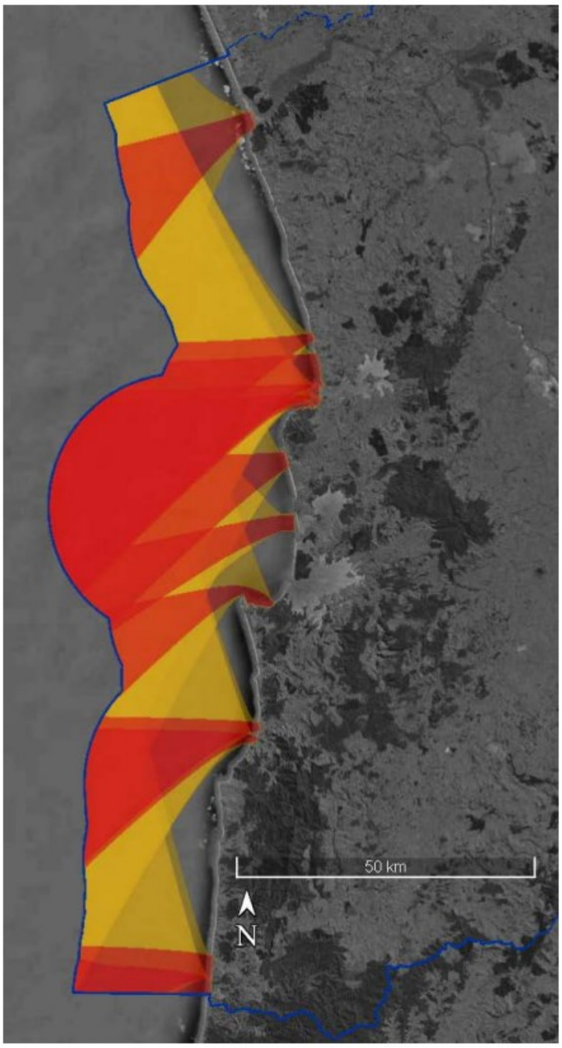


Figure 4.3: Planning tool for Waikato Regional Council constructed by Atkin and Mead (2017).The image shows swell corridors (red) and buffers zones (amber) GIS layers for Surf Breaks of Regional Significance on the Waikato region's west coast. The blue line is the regional boundary (blue).

4.4 Threats and Risk Assessment

Surf breaks are threatened by a wide variety of activities that can occur both naturally in the environment and from direct human impacts. Identifying potential and existing threats to surf break amenity requires a geographically wide consideration of activities, not only in the place where waves are being ridden but also in the associated swell corridor, surrounding waters, and on the adjacent land. It also requires consideration of the effects on "surfing capital"; the four factors that shape the surfing experience namely: 1) physical features and surfers' awareness of the quality of waves, 2) the frequency and quality of waves, 3) the coastal and marine environment and 4) the social and cultural issues associated with places (Lazarow 2010; Bourne and Ponting, 2017, p125).

Once a surf break has been identified, an assessment of the surrounding environment and an understanding of the kinds threats that are likely to occur in this environment is required. It is likely that the activities and developments that have the potential to threaten a surf break are broad and varied, and can include construction of new structures, disturbance of the seabed and foreshore, water quality and ocean outfalls, restricted access, changes to sediment supply and tidal currents.

Structures and disturbance of the physical environment that have the potential to impact on a surf break include activities and developments offshore (e.g. aquaculture, renewable energy, dredge disposal, seabed mining), in the nearshore and on the foreshore (e.g. ports, marinas, piers, coastal protection structures), within estuaries and harbours impacting on tidal prisms (e.g. marinas, causeways) and land-based developments that impact on water quality (e.g. wastewater treatment, processing plants, changes in land-use (e.g. urbanisation). It is likely that many of the risks and threats are ubiquitous across a region (Atkin and Mead, 2017). However, it is also likely that some surf break areas will be at risk to specific activities.

Surf breaks located proximal to harbours and estuaries are likely to be dependent on the hydrodynamics associated with the enclosed waters to maintain surfing conditions (e.g. Whangamata Bar); these types of surf breaks can be extremely sensitive to changes. Alterations to an enclosed water body by dredging activities or reclamation will change the tidal prism, and this can have knock on effects on local sediment transport processes; noting that attribution of these changes may be difficult to discern from natural variability and natural long-term evolution without well designed monitoring.

Water quality at surf breaks is linked with waterways and enclosed waters (harbours/estuaries). There are locations where storm or wastewater discharge to surf break areas; and if not directly, then currents can transport contaminated waters into SBAs. Discharges from forestry and farming activities occurring tens of kilometres inland and can be delivered to an SBA through waterways (e.g. Figure 4.4). These factors need to be considered when assessing the risks to surfing resources (Skellern *et al*., 2013).

Figure 4.4: Potential effects of land management. Allowing stock to access waterways has the potential to affect the environment in many different ways, some of which are keenly observed and felt by surfers who spend prolonged periods of time in the receiving waters. The effects are readily observed at delta breaks where rivers and estuaries discharge sediment and pollutant laden water into the coast. Left image shows waterway with no riparian separation (image: PhotoNZ) and right image an undisclosed river bar looking an uninviting shade of brown despite the high-quality waves on offer (image: J. Aubertin).

When determining the threat of an activity, the vulnerability and sensitivity of the receiving environment need to be considered. S*ensitivity is the degree to which the system responds to stresses, which are deviations of environmental conditions beyond the expected range; and* vulnerability is the probability that a feature will be exposed to a stress to which it is sensitive (Zacharias and Gregr, 2005).

When assessing risks to surfing resources the likelihood of an event leading to a consequence that is harmful to the environment needs to be considered. The threats presented in Section 2.3 provide a good starting point to assess risks to surfing resources., However, there are likely to be other site-specific activities and processes that have not been included. The likelihood of the activity having an impact on a surfing resource, including, but not limited to, surfing wave quality, coastal processes, access and amenity value, naturalness (environmental setting) and wilderness values, levels of use, economic value, and historical/heritage/cultural associations, also needs to be assessed.

It should be noted that activities can also impact on a surfing resources in a positive way, with improvements to fundamentals such as access and water quality. There is a history of engineering works improving surfing conditions, and in some cases creating a new surf break where there was none before (e.g. there are some occasions where coastal engineering works such as training walls, sand-bypassing and groynes/breakwaters have enhanced or created new surf breaks). However, this can be at the expense of existing resources, and the history between surfing resources and engineering works is largely dominated by degradation and destruction (Scarfe *et al*., 2009b). Many threats can be addressed, at least to some degree, by some management intervention action at source. Others, such as natural changes in wave climate or overcrowding at breaks due to population increase, cannot.

4.5 Cultural Impact Assessment

A useful tool to obtain iwi perspectives on a proposed environmental activity is a Cultural Impact Assessment (CIA). A CIA is a planning tool that helps to facilitate Māori participation in the planning process. The CIA report documents Māori cultural values, interests and associations with an area or a resource, and the potential impacts of a proposed activity on these. A resource consent applicant may commission a CIA and the report is regarded as technical advice. A CIA is not a statutory requirement for a resource consent application. However, an assessment can assist the applicant and consenting authority in responding to issues affecting local iwi. In this respect, a CIA can:

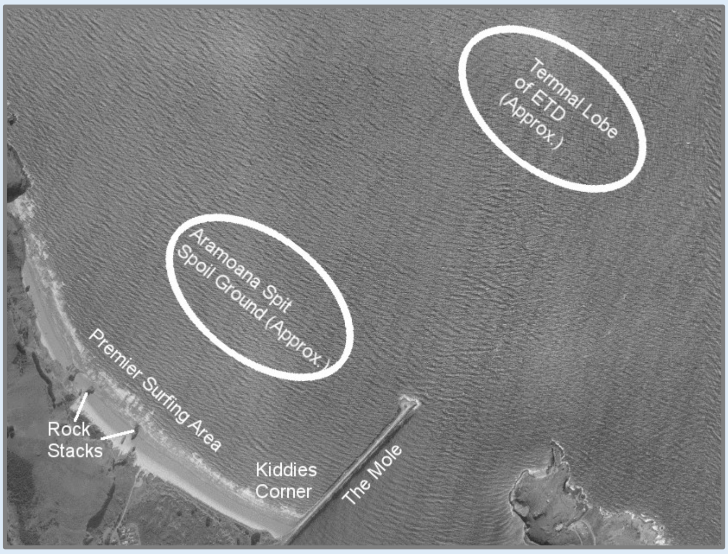
- Identify the effects of a proposed activity on local iwi cultural associations with the environment.
- Identify or assist identification and formulation of methods to avoid, remedy or mitigate adverse effects on cultural values and associations.
- Suggest what conditions of consent could be applied if consent is granted.
- Provide iwi with comprehensive information and improved understanding of the proposed activity.

A CIA can complement the attribute value data, and threats and risk assessment data to provide a rich assessment of the diverse values and interests that community/iwi/hapū have for surf breaks from varying perspectives. The development of a CIA is important as NZCPS Policy 2 requires councils to acknowledge Māori values and include them as part of the decision-making process. See Appendix C for resources relating to CIAs.

4.6 Surfing Resources in Policy and Plans

While Policy 16 does not state that regionally or locally significant surfing resources should be accounted for, the overarching ethos of the NZCPS is sustainable management and it provides polices to protects all surf breaks by ensuring recognition is given to outstanding natural character and natural features (See Section 1.2 Legislative Context). To date there is a significant list of cases in Aotearoa New Zealand where impacts on surf breaks have been recognised and incorporated into the AEE's for resource consent application and/or challenged in Environment and High Courts. These cases have not been restricted to the surf breaks named in Policy 16 of the NZCPS (2010), and include Town Reef (Napier), Kaituna Cut (Bay of Plenty), Mangamaunu (Kaikoura; SBNS), Takapuna Reef (Auckland), Whangamata Bar (Coromandel; SBNS), several breaks along the western Firth of Thames (Auckland), the Corner and Lyall Bay (Wellington), Taylor's Mistake (Christchurch), Whareakeake and Aramoana (Dunedin; SBNS), Titahi Bay (Wellington), Waiwhakaiho (Taranaki) and Waipaoa River Mouth (Gisborne).

Case Study: Dredge spoil surf



The Spit at Aramoana is one of the 17 Surf Breaks of National Significance. The wave quality is largely determined by the way in which waves are preconditioned by offshore bathymetry. Primarily, waves are focussed on the terminal lobe of the ebb tidal delta at the entrance channel to Otago Harbour; secondarily wave crests are modified on a historical nearshore spoil ground. The main threat to the surf break at Aramoana is the disposal of material in the nearshore spoil ground. Disposal began here in the early 1980s, at which time some of the best surfing conditions were reportedly experienced. Early in the 21st century there was a general concern that Aramoana was no longer providing the high-quality surfing waves that it had in the past. It was considered by some that continual addition of sand not only impacted the secondary preconditioning processes, but that the embayment had become over-full with sand forming a large shallow platform in the nearshore. After objections to a consent for increased disposal quantities a working party was formed comprising of representatives from Te Runanga Otakou, Kati Huirapa Runanga ki Puketeraki, Department of Conservation, Otago Regional Council, Surfbreak Protection Society, South Coast Board Riders Association, Aramoana Conservation Trust and Port Otago Limited. The working party agreed to a 3-year temporary permit with greatly reduced disposal at the nearshore site, combined with a monitoring and modelling investigation to determine the impacts of nearshore disposal at Aramoana. No dredge material was placed at Aramoana for the first 2 years, during which time it was perceived by all parties involved that surfing conditions had improved.

The consistent themes in Policies 13 (preservation of natural character) and 15 (natural features and natural landscapes) are identification and ensuring that there are specific objectives, policies and rules. It is recommended this approach is taken with surfing resources.

"*Planning approaches based on recognising a list of surf breaks of higher relative importance than others are a potential mechanism for achieving policy objectives, and similar concepts have been applied to the management of other natural resources"* (Orchard, 2017, p.11).

As previously discussed, while a hierarchy may work for some authorities, others may choose an alternative approach, individual break identification or such as a blanket protection for all surfing resources in the region. The latter may be applicable if it is simply too complex to discern between levels of significance, or there are so few surf breaks in a region that they all regionally significant.

4.7 Baseline Monitoring

Baseline monitoring is required in order to determine whether or not an activity impacts on a surfing resource. Baseline monitoring is focussed on the collection of data that can be used to characterise the surf break (i.e. length of ride, wave climate, tidal phases, peel angle, breaking intensity, local seabed morphology etc.). Baseline monitoring methods can include:

- Remote video data collection – this is most cost-effective method of collecting surf break data, which can be used to determine peel angles, ride length, optimum conditions, typical take-off and break location(s), infer seabed morphology, shoreline position and provide information such as number and type of users;
- Hydrographic surveys – repeat collection of bathymetric data provides information on the variability of the seabed;
- GPS tracking of surfers – can be applied to determine peel angles, ride length, take-off area, sections of the wave, and entry and exit points to the surf break;
- Beach profile monitoring – can use traditional surveying methods or Light Detection and Ranging (LiDAR);
- Numerical modelling – calibrated numerical models can be used to simulate the existing surf break during various wave events, as well as consider the potential impacts of any changes to the existing environment that may impact on the surf break (e.g. nearshore dredge disposal mounds, harbour channel deepening, offshore sand-mining, shoreline protection structures etc.);
- Water quality monitoring – activities such as nearshore dredge disposal, dredging, stormwater outfalls, wastewater outfalls, aquaculture, forestry, farming and urbanization can potentially impact on water quality.

Due to the natural variability and seasonality of the marine environment it is important to collect baseline monitoring data for as long as possible; multi-year datasets provide information on the effects of longer-term oceanographic variation such as El Nino/La Nina. See Appendix E for further discussion on surf break monitoring.

Water quality standards should follow Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment, 2002). However, sampling sites must be proximal to surfing areas, which can be significantly different to bathing areas (e.g. in a river mouth not central to beach), and should target the pollutant (e.g. some pollutants will be mixed throughout the water column, others may be in the upper layers (wastewater/stormwater is less dense than seawater), or lower layers (e.g. hypersaline water from desalination is denser than seawater)).

Surf break monitoring data can provide other valuable information for coastal management. For instance, remote video cameras can provide statistics on users of the coastal space (not only of surfers, but other water and beach users), erosion/accretion trends, the movement of rips and bars (e.g. safety issues), and information on extreme events and coastal hazards. There is an opportunity to incorporate surf break baseline data collection into any long-term environmental monitoring strategy.

4.8 Considerations for Consenting Authorities

A consenting authorities' obligation under the RMA (104(1)(b)) is to have regard to the NZCPS 2010. *The NZCPS 2010 will not determine whether or not an application is notified but may assist in identifying relevant effects to consider in a notification determination.* Appendix E provides information regarding consent conditions that can be applied to ensure that an activity does not adversely affect a surfing resource. The consent conditions required will vary from site to site and the responsibility to ensure compliance with the consent conditions will often fall to an authority's coastal expert. Considerations for the consenting process include:

- A precautionary approach should be taken if there is any potential for impacts on a surfing resource. In almost cases there will no data available on the existing resource.
- It is the conditions of consent that are fundamental to ensuring that not only is the monitoring design appropriate to detect and quantify effects, but also include methods that counter these effects through avoidance, remedying or mitigation.
- A correctly undertaken CIA will ensure iwi perspectives are included in the consenting process.
- Activities well outside of the CMA can potentially impact on surfing resources, both inland and offshore. Consideration in the context of the NZCPS should be given to

surfing resources where an activity is being undertaken on or adjacent to any waterway in the coastal hinterland.

- Impacts on surfing resources need to be evaluated on a case by case basis and the consequence of cumulative impacts need to be considered.
- Surf science is a very specialist field and it is likely that most coastal scientists will have little to no experience or exposure to surf science as it is not readily taught at any institution in Aotearoa New Zealand. Depending on the nature of the consent application, it may be prudent to engage a specialist surf scientist with a track record in studying natural surf breaks and surf break mechanics.
- The RMA controls specific uses of natural and physical resources through the requirement of a resource consent. In order to gain resource consent for specific activities, an Assessment of Environmental Effects (AEE) is required in an application.
- Water quality issues are significant for surfers, and more so than average water users, as they are often exposed to the environment for prolonged periods of time. Many surf breaks are located next to or near to rivers and estuaries, and it is common practice in Aotearoa New Zealand to direct stormwater in to the nearshore. Water quality standards should follow *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* (Ministry for the Environment, 2002). However, sampling sites must be proximal to surfing areas, which can be significantly different to bathing areas (e.g. in a river mouth not central to beach), and should target the pollutant.

4.9 Detailed Characterisation

Detailed characterisation of a surfing resource requires an amalgamation of various investigative methods to determine peel angles, ride length, optimum conditions, breaking intensity and the variety of other surf break characteristics (breaking intensity, take-off zone(s), sections, etc.).

Numerical modelling is a valuable and cost-effective approach, and a critical step in detailed characterisation is model calibration. Calibration is achieved by the collection of environmental data at the site of interest. In the case of surf breaks, this would primarily include wave, current and water level data; calibration may also benefit from the collection of wind and pressure data.

To establish an accurate wave climate (e.g. Figure 4.5), a combined model that simulates water level, currents, wind and waves is required. This calibrated, combined model can be used to develop boundary conditions for more detailed models that consider complex wave breaking and sediment transport processes. In addition to surf break characterization, any changes to waves and currents induced by a proposed activity have the capacity to impact on the seabed morphology at a surf break. Therefore, sediment transport and morphological modelling are a critical step in a surf break AEE.

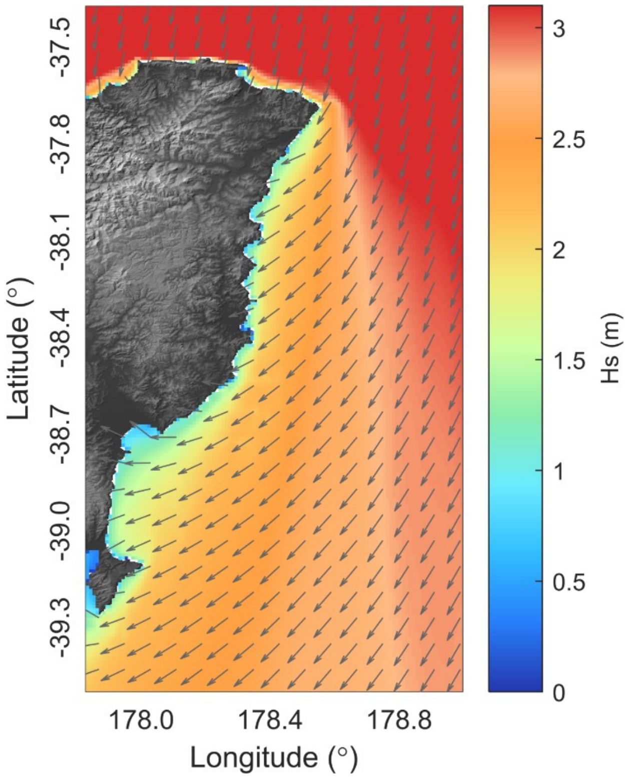


Figure 4.5: Example of numerical model output of wave height (left colour bar) and direction (arrows) around the East Cape during Tropical Cyclone Ivy's passage down the east of the North Island in 2004.

Wave breaking is extremely dynamic and a numerical model using higher-order approximations of the processes of wave propagation, shoaling and breaking is required. Higher-order numerical models are generally referred to as phase resolving models[9]. These models look at waves individually, rather than in an averaged way like those models used to simulate wave climate. Certain situations will require Computational Fluid Dynamics (CFD). A common branch of CFD is Smooth Particle Hydrodynamics (SPH). These types of models run 3-dimensional simulations of particles and can provide a further insight in to the dynamics of surfing waves. SPH is particularly useful for understanding situations where waves exhibit high breaking intensities over low seabed gradients. This type of scenario can be the result of

[9] Some phase resolving models are based on the Boussinesq approximation. Therefore, the terms are often used in tandem, however, there are non-Boussinesq-type phase resolving models.

disruptive focusing or wave reflections, or a combination of both. Where post processing of phase resolving models would indicate low breaking intensities over the low seabed gradients, SPH output can exhibit wave shape in line with what is observed in reality.

Sediment transport modelling is complex and requires data relating to the sediment types at the study site and input conditions from a combined model. However, taking in the context of coastal processes and in situ measurements, in some cases they are an invaluable tool to aid with the understanding and characterisation of surf breaks. There are different approaches to sediment transport modelling, with characteristic and reduced wave climates being employed to simulate long term morphodynamics. Ultimately, sediment transport modelling considers how (beach) morphology changes over time, this can then be used in conjunction with detailed wave breaking models to determine how these changes effect surfing wave quality. Because sediment transport modelling looks at changes to the seabed, an appropriate method for validating the model is to undertake repeat hydrographic surveys to collect bathymetric data.

Case Study: Bigger planes, smaller waves

At Lyall Bay in Wellington there are several peaks for surfing along the beach. The premier surf break is a left-hander called “The Corner” (also known as “The Wall”). The Corner is a modified beach break that benefits from wave preconditioning by the interaction of incident wave crests with the airport runway sea wall. In 2015, plans were announced to extend the airport runway into the bay by 350 m to accommodate larger airliners. The extension will cover and destroy the rarely surfed big wave spot of Airport Rights, and reduce surfing amenity throughout Lyall Bay. Initial impact studies indicated that there will be a reduction in the number of good surfing waves. Anecdotal evidence suggests that the wave quality in the “The Corner” has, over the past years, already been negatively affected by several factors including a reduction in the reflectivity of the wall as sheet piling has been progressively covered in rock rip rap, a widening of the rock revetment, and a carpark extension. Changes to the nearshore wave climate are likely to result in changes in wave-driven currents, which may alter the seabed morphology, and consequently surfing waves as they propagate shoreward. Whether the impact will be negative or positive is currently unknown and not yet investigated adequately. A multipurpose reef has been proposed as mitigation for the loss of surfing amenity.

The most practical and useful times for collecting bathymetric data are whilst instrumentation is deployed to collect environmental data. This allows a direct evaluation between bathymetric data and actual (not simulated) forces (waves, water level and currents) that drive shoreline change.

The versatility of a calibrated numerical model is enhanced by additional data collection that can be used to validate the model outputs and will also often be necessary for baseline monitoring data. For example, remote video imagery can be used to validate particular swell events in terms of wave peel angles, and GPS tracking of surfers can provide additional confidence in surf break characterization and numerical modelling by identifying aspects such as take-off zones and ride lengths. As detailed in Appendix E remote video and GPS tracking are an important part of surf break monitoring.

5 Summary and Outlook

These guidelines provide a background to mapping, assessing and quantifying surfing resources within Aotearoa New Zealand. The document aims to clearly present stakeholders with the considerations concerning surfing resources for use in either preparation of consent applications, assessing submitted consent applications, or in submissions on applications.

The guidance provided is within the context of the Resource Management Act 1991 and the NZCPS 2010. Planning and policy documents are likely to require explicit recognition of surf breaks, and provisions for surfing resources are likely necessary for their protection and management as natural resources in Aotearoa New Zealand.

The main body of this document sets out a framework to aid in managing surfing resources. For authorities the key steps are:

Step 1 Identifying and mapping surf breaks.
Step 2 Mapping swell corridors.
Step 3 Identifying threats and risk assessment.
Step 4 Incorporating surf break provisions into policy and plans.
Step 5 Baseline studies
Step 6 Baseline monitoring

For Resource users and consent applicants the key steps are:

Step 1 Identification of surf breaks, swell corridors and threat/risk assessment
Step 2 Detailed characterisation

There are a number of key concepts and ideas that require consideration:

- Surfing resource boundaries are part of a shared ecosystem encompassing the beach, the sea, the catchment and stakeholder interests.
- Surfers are coastal environment stakeholders, they form influential lobby groups (e.g., SPS), and others are traditional resource custodians (Iwi).
- Surfing capital, the four factors that shape the surfing experience are 1) physical features and surfers' awareness of the quality of waves, 2) the frequency and quality of waves, 3) the coastal and marine environment, and 4) the social and cultural issues associated with places.
- Different sites are valued for different aspects (wilderness, big waves or easy access)
- Surfers do not only surf for 'the thrill of the ride'. The sense of freedom of riding the wave, the connection with the elemental forces of the wave, the aesthetics of the

surrounding landscape, the social interactions with mates, and the coastal environmental quality all contribute highly to the surfing experience. As a consequence, all these factors need to be accounted for in managing the resource and threats against it.

- Surfing is a growing sport, as are water activities, so competition for space will increase.
- Threats to surf breaks come from the land and sea and for cultural reasons.
- It is possible to enlist the help of the general public to collect information on surf breaks (referred to as citizen science).
- Numerical modelling is a powerful tool to understand the effects of changes in the surf break environment to a high level of detail.
- Output from monitoring is inherently limited because of the high degree of natural variability. Long term changes to our wave climate drive interannual changes to morphology and the characteristics of wave conditions at surf breaks, and anthropogenic changes need to be greater than natural changes to allow detection of anthropogenic effects.

Looking ahead, and as the number of participants using surf breaks continues to grow there will be more pressure on the known surfing resources. This will result in a change of use, whereby users frequent lesser known surf breaks to enhance their own enjoyment. Access to the lesser known and ‘hard to get to surf breaks” may also be facilitated by access via new roads or watercraft. In some areas the reverse may happen and access to know surf spots may be restricted. It is therefore recommended that the list of surf breaks and the value rankings for breaks in a council region should be reassessed prior to each iteration of the coastal plan and/or at a time frame deemed suitable by the council that allows for breaks to be included on time scales consistent with population growth, and demographic and social change.

6 Glossary

Big wave surfing – a sub-discipline of surfing focussed on riding the largest of waves. This sometimes requires the use of larger than average surf boards or for surfers to be towed-in to the wave by a jet ski (personal watercraft). Big wave surfers undertake specialist training and the sub-discipline has fewer dedicated participants. Big wave surfing locations are relatively sparse in time and space with very particular seabed configurations and incident swell conditions required. A big wave surf break can be referred to as **Bombora**.

Clean – best conditions for surfing and occur in conjunction with light or offshore winds (i.e. there are no local winds creating additional swell components; see below; see Appendix A). Mixed swells occur when there are several wave direction and period components occurring at the same time. Clean swell has a narrow spectral width, while mixed seas have wide spectral width.

Iwi – the largest Māori social unit. Iwi can be translated as 'tribe'. All Iwi throughout the Aotearoa New Zealand have a vested interest in their respective geographical region.

Kaitiaki - a person, group or being that acts as a guardian, carer or protector.

Kaitiakitanga - the exercise of guardianship by the Iwi of an area in accordance with Māori values and customs in relation to natural and physical resources and include the ethic of stewardship.

Offshore wind – wind direction and wind strength are important factors with respect to surfing wave quality. Typically, light local winds provide ideal surfing conditions. Offshore winds are directed in the opposite direction to incident wave crests and can "**clean**" wave faces making for improved surfing conditions. the direction of offshore wind is generally stated as direction coming from (e.g. southerly) and is considered the optimum wind condition. It should be noted that preferred wind direction is as subjective as surfing wave quality and comes down to participant choice.

Peak – the part of the wave which breaks first and so is also known as the take-off. Wandering or shifting peaks means that there is no defined take-off zone.

Peel – surfers require a clean unbroken wave face for performing surfing manoeuvres. In order to ride the wave for as long as possible, the wave must peel where the breaking part of the wave crest translates laterally across the face of the wave. This is opposed to a wave that breaks simultaneously along its length, which is referred to as a "close-out". Waves can peel fast or slow.

Rohe – is the region or land that forms the tribal boundary of a particular Iwi.

7 Acronyms

AEE – Assessment of Environmental Effects

CIA – Cultural Impact Assessment

CMA – Coastal Marine Area

GPS – Global Positioning System

KSC – Known Surfing Coastline

LiDAR – Light Detection and Ranging

MBIE – Ministry for Business, Innovation and Employment

NZCPS – New Zealand Coastal Policy Statement

RPA – Relative Percent Activity

RMA 1991 – The Resource Management Act

SBA – Surf Break Area

SBLS – Surf Breaks of Local Significance

SBNS – Surf Breaks of National Significance

SBRS – Surf Breaks of Regional Significance

SUP – Stand Up Paddleboard

WSR – World Surfing Reserve

8 References

ASBPA 2011. Surfers as Coastal Protection Stakeholders. American Shore and Beach Preservation Association. White Paper.

Atkin, E. A., 2017. Known Surfing Coastlines in the Waikato Region. eCoast Letter Report for Waikato Regional Council.

Atkin, E.A and Greer D., 2019. A Comparison of Methods for Defining a Surf Break's Swell Corridor. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.

Atkin, E.A. and Mead, S.T., 2017. Surf Breaks of Regional Significance in the Waikato Region. Waikato Regional Council Technical Report 2017/19. 64pp.

Atkin, E. A., Gunson, M. and Mead. S. T., 2015. Regionally Significant Surf breaks in the Greater Wellington Region. eCoast technical report for Greater Wellington Regional Council.

Atkin, E., Mead, S. T., Bryan, K., Hume, T. and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. Proceedings of the 23rd Australasian Coasts and Ports Conference, Cairns, Australia, 21-23. June 2017.

Auckland Council, 2018. Auckland Unitary Plan. Accessed June 2018, <http://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=Auckland UnitaryPlan_Print>

Ball, S., 2015. The Green Room: A Surfing-Conscious Approach to Coastal and Marine Management. UCLA Journal of Environmental Law and Policy, 33 (2).

Beattie, H. 1919. Traditions and legends collected from the natives of Murihiku (Southland, New Zealand). The Journal of the Polynesian Society, 28(XI), 212–25.

Benedet, L., Finkl, C.W. and Hartog, W.M., 2007. Processes controlling development of erosional hot spots on a beach nourishment project. Journal of Coastal Research, 23 (1) pp.33-48.

Best, E. 1924. *Games and pastimes of the Maori*. Wellington, New Zealand: A. R. Shearer.

Bhana, M., 1996. New Zealand Surfing Guide. Revised ed. Auckland: Reed Books.

Black, K. P., 2007. Review of Wave Hub Technical Studies: Impacts on inshore surfing beaches. Prepared for South West of England Regional Development Agency, North Quay House' Sutton Harbour, Plymouth.

Board of Inquiry, 2009a. Proposed New Zealand Coastal Policy Statement 2008 Report and Recommendations Volume 2: Working Papers. Accessed 1 October 2014 from http://www.doc.govt.nz/upload/documents/getting-involved/consultations/closedconsultations/nzcps/NZCPS-2008-board-of-inquiry-vol-2.pdf

Board of Inquiry, 2009b. Proposed New Zealand Coastal Policy Statement 2008 Report and Recommendations Volume 1: Findings, Recommendations and Recommended New Zealand Coastal Policy Statement (2009). Accessed 1 October 2014 from http://www.doc.govt.nz/upload/documents/getting-involved/consultations/closedconsultations/nzcps/NZCPS-2008-board-of-inquiry-vol-1.pdf

Borne, G. and Ponting, J., (Eds) 2017. Sustainable Surfing. Routledge, Oxon and NY. 261pp.

Borne, G., 2018. Surfing and Sustainability. London: Routledge.

Dahm, J. 2013. Dune management at Piha – Review and proposed management plan. Report prepared for Auckland Council Prepared by J Dahm, Eco Nomos Ltd Version 2 – October 2013. 38p.

Dally, W.R. and Osiecki, D.A., 2018. Evaluating the Impact of Beach Nourishment on Surfing: Surf City, Long Beach Island, New Jersey, USA. Journal of Coastal Research, 34 (4), pp. 793 – 805.

Department of Conservation, 2017a. Review of the effect of the NZCPS 2010 on RMA decision-making. Part 1 – Overview and key findings. Prepared for the Minister of Conservation by the Department of Conservation. [Online] <https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/coastal-management/review-of-effect-of-nzcps-2010-on-rma-part-one.pdf>

Department of Conservation, 2017b. Review of the effect of the NZCPS 2010 on RMA decision-making. Part 2 – Background information. Prepared for the Minister of Conservation by the Department of Conservation. [Online] < https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/coastal-management/review-of-effect-of-nzcps-2010-on-rma-part-two.pdf>

Durie, M. H., 1998. Te mana, te kāwanantanga: The politics of Māori self-determination. Auckland: Oxford University Press. 288p.

Edwards, A.M., 2012. Surf Break Co-Management: Options for the protection and enhancement of surf breaks in New Zealand. Master of Planning, Otago University, New Zealand.

Farmer, B. and Short, A. D., 2007. Australian National Surfing Reserves – rationale and process for recognizing iconic surfing locations. Journal of Coastal Research, SI 50, 99-103.

Flocard, F. and Hoeke, R.K., 2017. Coastal Protection through Wave Farms: Feasibility Assessment using Numerical Wave Modelling and Parametric Study. Proceedings of the Australasian Coasts and Ports Conference 2017, Cairns, Australia.

Grace, M. 2010. Wai Māori - Māori values in Water. Wellington, New Zealand: The Greater Wellington Regional Council. Report 10.449. 9p.

Hilton, M.J. 1989. Management of the New Zealand Coastal Sand Mining Industry: Some Implications of a Geomorphic Study of the Pakiri Coastal Sand Body. NZ Geographer 45 (1): 14-25.

Hume, T., Gorman, R., Green, M. and MacDonald, I., 2013. Coastal Stability of the South Taranaki Bight – Phase 2 Potential Effects of Offshore Sand Extraction on Physical Drivers and Coastal Stability. NIWA Client Report HAM2012-083: 135.

Lazarow, N 2010. Managing and valuing coastal resources: An examination of the importance of local knowledge and surf breaks in coastal communities. PhD Australian national University, Canberra.

Liria, P., Garel, E. and Uriarte, A., 2009. The Effects of Dredging Operations on the Hydrodynamics of an Ebb Tidal Delta: Oka Estuary, northern Spain. Continental Shelf Research, 29, p1983-1994.

Mach, L., Ponting, J., Brown, J., and Savage, J., 2018. Riding waves of intra-seasonal demand in surf tourism: analysing the nexus of seasonality and 21st century surf forecasting technology. Annals of Leisure Research, 1-19.

Makgill R.A. and Rennie H.G., 2012. A Model for Integrated Coastal Management Legislation: A Principled Analysis of New Zealand's Resource Management Act 1991. The International Journal of Marine and Coastal Law (27), p.135–165.

McGregor, T. and Wills, S., 2016. Natural Assets: Surfing a wave of economic growth. Economics Working Papers Series, 6.

Mead, S. T., 2000. Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs. Doctor of Philosophy, University of Waikato, New Zealand. Pp 209 + appendices.

Mead, S. T. and Black, K. P., 2001a. Field Studies Leading to the Bathymetric Classification of World-Class Surfing Breaks. Journal of Coastal Research, Issue Special Issue No. 29, pp. 5-20.

Mead, S. T. and Black, K. P., 2001b. Functional Component Configurations Controlling Surfing Wave Quality at World-Class Surfing Breaks. Journal of Coastal Research, Special Issue No. 29, pp. 21-32.

Mead S. T. and Black, K. P., 2001c. Predicting the Breaking Intensity of Surfing waves. Journal of Coastal Research, Special Issue No. 29.pp. 51-65.

Mead, S. T., 2013. Potential Effects of Trans-Tasman Resources Mining Operations on Surfing Breaks in the Southern Taranaki Bight. Report prepared for NIWA, October 2013.

Ministry for the Environment, 2002. Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Wellington: Ministry for the Environment.

Morse and Brunskill, 2004. Wavetrack New Zealand Surfing Guide. Greenroom Surf Media Ltd, Mount Maunganui.

New Zealand Coastal Society, 2014. Rena: Lessons Learnt. NZCS Special Publication. 24p.

NZSurf Guide, 2013. NZ Surf Guide. [online] Available at: <http://www.nzsurfguide.co.nz>.

Orchard, S., 2017. Regional Significance Criteria for the Assessment of Surf Breaks. Waterlink technical report prepared for Taranaki Regional Council.

Orchard, S., Atkin, E.A. and Mead, S.T., 2019. Development of the Regional Significance Concept for Surf Break Management in Aotearoa New Zealand. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 23–34. Coconut Creek (Florida), ISSN 0749-0208.

Osmond, G., 2010. Honolulu Māori. New Zealand Journal of History, 44 (1): 22-34.

Peryman, B., 2011a. Bay of Plenty Surf Break Study. Technical Report for Bay of Plenty Regional Council.

Peryman, B., 2011b. Surf Break Identification and Protection in the Gisborne District. Technical Report for Gisborne District Council.

Peryman, B. and Skellern, M., 2011. Planning Tools for Surf Breaks. New Zealand Coastal Society: Coastal News (46).

Peryman, P. B., and Orchard, S., 2013. Understanding the Values and Management Needs of New Zealand Surf Breaks. Lincoln Planning Review, 4(2): 8-18.

Pitt, A., 2009. Surfing at Bombora Controlled Beaches. The 5th Western Australia Coastal Conference, Freemantle, WA.

Pitt, A., 2010. Proposal for an Ephemeral Bombora at Cronulla. Report Prepared for the Bate Bay Sand Place Committee, Cronulla, NSW.

Plew, D. R, 2005. The Hydrodynamic Effects of Long-line Mussel Farms, PhD Thesis, University of Canterbury.

Rainger, T., 2011. The New Zealand Good Beach Guide: North Island. Raglan: Clean Media Ltd.

Reineman, D. R., Thomas, L. N. and Caldwell, M. R., 2017. Using Local Knowledge to Project Sea Level Rise Impacts on Wave Resources in California. Ocean and Coastal Management, 138: 181-191.

RMA 1991. The Resource Management Act 1991. http://www.mfe.govt.nz/rma

Salganik, M.J., and Heckathorn, D.D., 2004. Sampling and Estimation in Hidden Populations Using Respondent-Driven Sampling. Sociological Methodology, 34(1): 193-240.

Scarfe, B., 2008. Oceanographic Considerations for the Management and Protection of Surfing Breaks. PhD thesis, University of Waikato, New Zealand. 307p + appendices.

Scarfe, B. E., Elwany, M. H. S., Mead, S.T. and Black, K. P., 2003. The Science of Surfing Waves and Surfing Breaks - A Review. Proceedings of the 3rd International Surfing Reef Symposium, Raglan, New Zealand, June 22-25, 2003. p37-59.

Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T., 2009a. Sustainable management of surfing breaks: an overview. Reef Journal, 1(1), 44–73.

Scarfe, B. E., Healy, T. R., Rennie, H. G., and Mead, S. T., 2009b. Sustainable Management of Surfing Breaks: Case Studies and Recommendations. Journal of Coastal Research, 25(3), 684–703.

Selby, R., Moore, P., and Mulholland, M. (eds.). 2010. Māori and the environment: kaitiaki. Wellington: Huia Publishers.

Short, A. D., and Farmer, B., 2012. Surfing Reserves – recognition for the world's surfing breaks. The Reef Journal, 2, 1-14.

Skellern, M., Rennie, H.G., and Davis, M., 2009. Working towards the protection of surf breaks. Planning Quarterly172: 12-15.

Skellern, M., Peryman, P., Orchard, S. and Rennie, H., 2013. Planning Approaches for the Sustainable Management of Surf Breaks in New Zealand. Report prepared for

University of Auckland, Auckland Council, Bay of Plenty Regional Council and Surf Break Protection Society. 87pp.

Taranaki Regional Council (2016). Draft Regional Coastal Plan, August 2016. Taranaki Regional Council.

Smallman, E. R., 2018. 'If someone gets hit, they are going to get hurt'. Stuff. https://www.stuff.co.nz/national/103177002/if-someone-gets-hit-they-are-going-to-get-hurt

Tau, T. M., Goodall, A., Palmer, D., and Tau, R., 1990. Te Whakatau Kaupapa – the Ngāi Tahu Resource Management Strategy for the Canterbury Region. Aoraki Press: Ōtautahi Christchurch.

Taylor, P., and T. Dempster, 2016. Effects of salmon farming on the pelagic habitat and fish fauna of the Marlborough Sounds and management options for avoiding, remedying, and mitigating adverse effects. Wellington: Ministry for Primary Industries. Available at: https://www.mpi.govt.nz/dmsdocument/16138-effects-of-salmon-farming-on-the-pelagic-habitat-and-fish-fauna-of-the-marlborough-sounds-and-management-options-for-avoiding-remedying-and-mitigating-adverse-effects/sitemap

The United Nations General Assembly. 2007. Declaration on the Rights of Indigenous People.

Usher, L, E., 2017. Sustaining the Local: Localism and Sustainability. pp. 147-164 in Borne, G. and Ponting. Sustainable Surfing. Routledge London and New York 261p.

Walker, R., 2004. Ka whawhai tonu matou: Struggle without end (2nd ed.). Auckland: Penguin Books (NZ) Ltd.

Zacharias, M. A. and Gregr, E. J., 2005. Sensitivity and Vulnerability in Marine Environments: An Approach to Identifying Vulnerable Marine Areas. Conservation Biology, 19: 86-97.

Appendix A. **Physical Surf Science**

A.1 Introduction

Since the first relevant surfing specific studies back in the 1970's (Walker, 1972; Kelly, 1973), the collective global knowledge regarding the multiple disciplines of the surfing consciousness has grown considerably. While social, cultural and economic ("Surfonomics") studies are imperative to an understanding of surfing resources, this appendix describes the physical science which forms the foundation for surf breaks characterisation and management.

The history of physical surf science is firmly embedded in oceanographic research and classic surface wave theory; and for that reason, some basic oceanographic concepts are presented. The rest of this appendix is presented to give the reader a basic understanding of surf break composition; quantification of surfing waves; and factors effecting surfing wave processes. "*Understanding and quantifying the various features that combine to produce a surfing break at a particular location are implicit to the determination of the impacts of any potential alterations to a particular break*" (Mead and Borrero, 2017).

A.2 Basic Oceanographic Concepts

This section provides introductory information to surface wave theory to assist readers in understanding the processes occurring at surf breaks. At most surf breaks, the waves that are ridden are wind generated. Some exceptions include those surf breaks that rely on boat wakes (which, at time of writing, there were none known of in Aotearoa New Zealand) and standing/river waves.

Surface waves in deeper water are characterised in the same classical way as that of transverse, sine waves (Figure B-1). Wave height is the distance, or the change in vertical height, between the peak or crest and trough of the wave; (where the crest is the top, or most elevated part of the wave, and the trough is bottom or lowest part) in-between consecutive wave crests. Wave amplitude is half the wave height. Wavelength is the horizontal distance between consecutive crests (or troughs). Wave period is the time interval for two successive peaks (or troughs) to pass a fixed point in space.

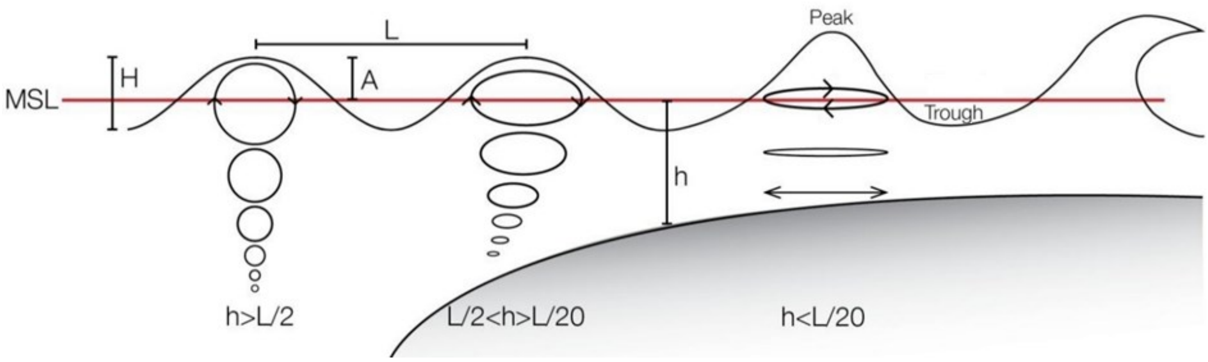


Figure B-1: Simplified, not to scale diagram of basic wave theory and nomenclature; showing wave height (H) relative to mean sea level (MSL), wave amplitude (A), wavelength (L), depth (h) and the characteristics of wave orbits.

Waves are generated by wind blowing over a water bodies surface. Surfing waves can be generated by weather systems several 1000’s of kilometres away from the surfing location; or they can be surfed with in the same weather system that generates them.

Regardless of the generation source and location, the fundamental processes are:

1) propagation - the movement of energy through the medium of water as waves.
2) refraction – the modification and often redistribution of wave energy as the waves interacts with the seabed.
3) shoaling – reduction in the speed of waves, resulting in increases in wave height steepness.

4) breaking – the dissipation of wave energy as it becomes unstable.

Processes 2, 3 and 4, for the most part in terms of surfing, and with a number of caveats, are reliant on the configuration of the seabed. This is because the energy within an individual wave is not just present with in the surface but is transferred down through the water column at all times to a depth that is representative of the wavelength (Figure B-1).

Wave orbitals are the common, theoretical interpretation of this energy transfer down through the water column. When a wave is in a depth of water that is shallow enough for the wave orbitals to interact with the seabed, which is taken as being less the half of a wavelength, it will start to transform.

These transformations are governed by the way a wave interacts with the seabed because this interaction moderates the speed at which can travel; wave speed (celerity) is dependent of water depth, the shallower the water, the slower the wave speed. Changes along a wave's crest in the speed it can travel results in refracting (or bending; Figure B-2). These same interactions control the extent of shoaling a wave undergoes, and the shape of the seabed in profile is responsible for the style and shape in which a wave will break.

Wiegel (1964) and later Galvin (1968) described wave breaking type as one of four terms: spilling, plunging, collapsing or surging (Figure B-3). Battjes (1974; after Galvin (1968); after Iribarren and Nogales, 1949) presented critical transitional values for each breaker type where the seabed slope (S), the offshore wavelength ($L\infty$) and the offshore or inshore wave height (Hb or $H\infty$) can be used to predict the dimensionless Iribarren number (or surf similarity parameter): $\zeta = S/(H/L)0.5$

The seabed slope is critical in the Iribarren number. Of the different types of breaking waves prescribed it is those that are spilling and plunging that are most useful for surfing, with those in the plunging category most sort after by surfers. It should be noted though that there is significant interested in collapsing waves, or at least surfing breaks that have a collapsing section of element to them.

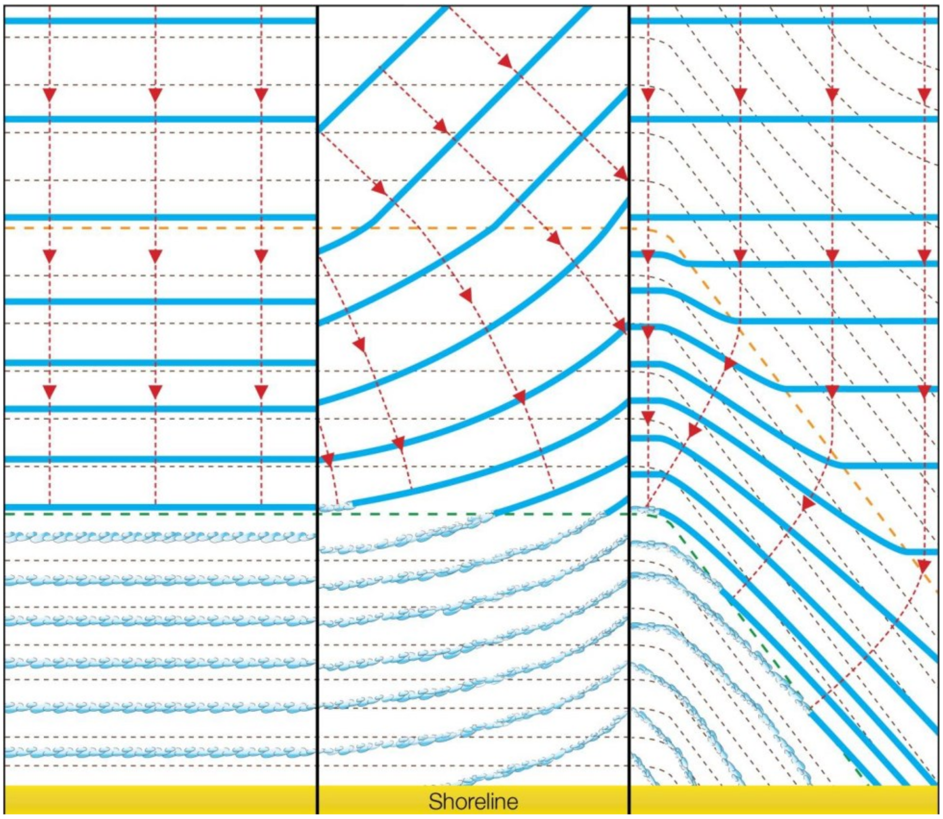


Figure B-2: Illustration of wave refraction, wave rays and breakpoints. Solid blue lines represent waves approaching the coast, red dashed lines are wave rays. Grey dashed lines are isobaths, decreasing in depth toward the shoreline. Orange dashed line represents the isobath at which deep-water waves start the transition to shallow water waves and begin to refract. Green dashed line represents an isobath equal to 0.78Hb, the wave breaking depth. Left: Waves approaching the coast parallel to the local isobaths, no refraction occurs. Wave rays remain parallel, and the wave breaks simultaneously along its length. Middle: Obliquely incident waves refract on shore parallel isobaths; the break point translates laterally across the wave face. Right: Waves approaching shore normal, but refraction occurs as the isobaths are oblique to the wave crest (From Atkin, 2010).

This subsection provides a simplified description of the processes that occur as waves travel to a Surf Break Area (SBA). It delivers two fundamental concepts:

- **Waves for surfing come from a range of sources**
- **The seabed both inside and outside the SBA is imperative to the processes that create surfing waves**

Butt and Russel (2002) provide further surf science related details on surface wave theory.

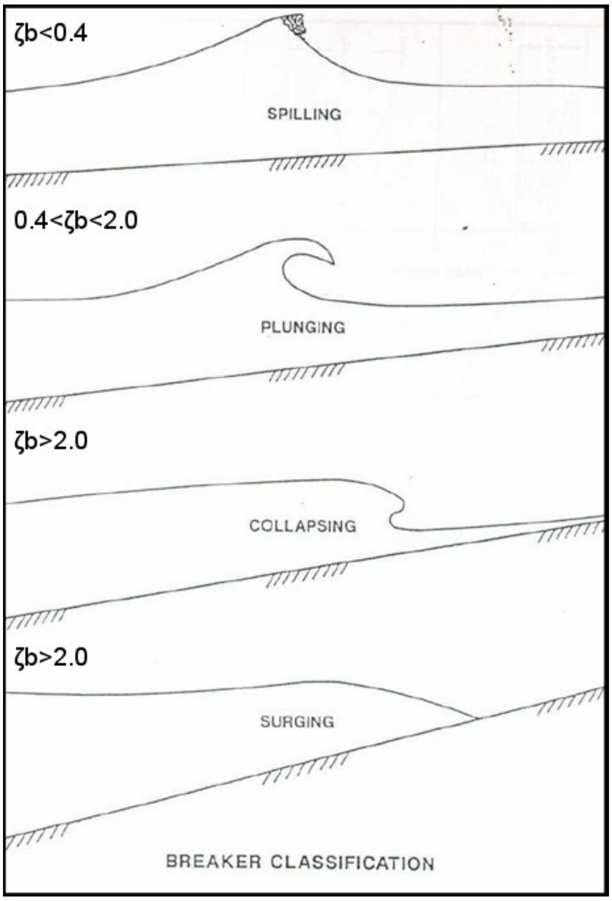


Figure B-3: Breaker type classification (adapted from Battjes, 1974)

A.3 Measurements of Surfing Waves

Wave breaking characteristics are critical to the surfing experience. The body of literature regarding surf science is largely concerned with the wave shape and the speed at which a wave breaks along its crest. When discussing surfing waves, wave shape is referred to as breaking intensity; and, the speed at which a wave breaks is quantified as peel angle. These factors are discussed concisely in Mead and Borrero (2017).

The fundamental concept of wave breaking is that the peak or crest of the wave becomes unstable and is projected forward in the direction of wave travel. This instability is a result of shoaling, where wave height increases, and the wave front becomes steeper; and there is an inequality in the speed at which different parts of the wave are travelling – the drag imposed by the seafloor is greatest close to the seafloor and decreases at the peak/crest causing the top part of the wave to pitch forward and the wave to eventually break.

A.3.1 Peel Angle

Good surfing waves break in a 'peeling' manner whereby the breaking part of the wave translates laterally along a wave crest. The peel angle is defined as the angle between the trail of broken white water and the crest of the unbroken part of the wave (Walker *et al.*, 1972, Figure B-4). Peel angle is directly related to the rate at which the breaking part of the wave translates, or the speed at which a wave is breaking.

If a wave breaks along the length of its crest simultaneously the peel angle is zero degrees. This scenario is termed a 'close-out' in surfing culture. If the breaking part of the wave does not translate along the crest at all then the peel angle is 90 degrees. Small peel angles indicate waves that break faster than those with a high peel angle.

Walker (1972) and later Hutt *et al.* (2001) categorised surfing waves in terms of difficulty based on the peel angle. The Hutt *et al.*'s (2001) scheme considers skill levels from absolute beginner to waves beyond the current highest skill level (Table B-1)

Mead and Borrero (2017) note that "while the modern classification scheme is a useful tool… it is based upon a single peel angle value for a particular surf break. In reality, surf breaks can have several 'sections' with different surfing characteristics". Moores (2001) considered the length and peel angles of wave sections for a single surf break using videography techniques. Moores' work validated the scheme of Hutt *et al.* (2001). While the understanding of surf break dynamics was increased, a void on how peel angle changes over space and time still remains.

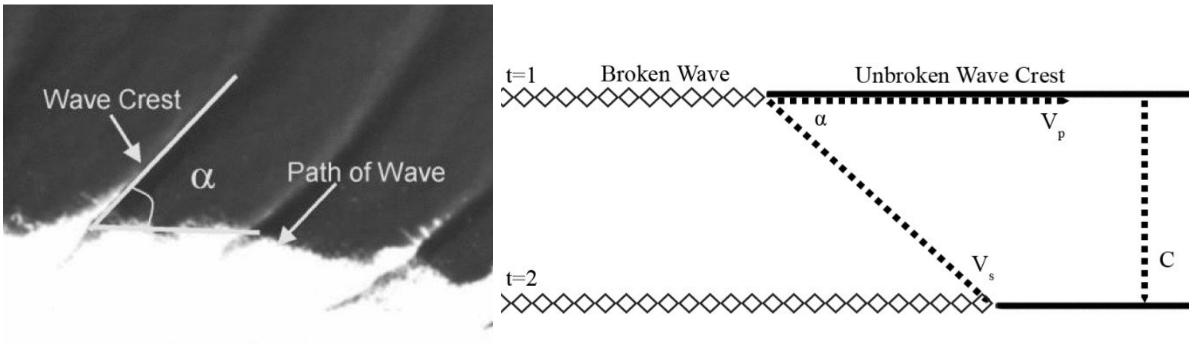


Figure B-4: Annotated aerial photograph (left) and schematic diagram of wave peel angle (α), peel rate (Vp), down the line velocity (Vs) and wave speed (c) (adapted from Walker, 1972; van Ettinger, 2005). (right).

Table B-1: Rating of the skill level of surfers. Ratings are independent of surf break quality or the degree of difficulty of waves (Hutt *et al.*, 2001).

Rating	Description of Rating	Peel Angle Limit (deg)	Min/Max Wave Height (m)
1	Beginner surfers not yet able to ride the face of a wave and simply moves forward as the wave advances.	90	0.70 / 1.00
2	Learner surfers able to successfully ride laterally along the crest of a wave.	70	0.65 / 1.50
3	Surfers that have developed the skill to generate speed by 'pumping' on the face of the wave.	60	0.60 / 2.50
4	Surfers beginning to initiate and execute standard surfing maneuvers on occasion.	55	0.55 / 4.00
5	Surfers able to execute standard maneuvers consecutively on a single wave.	50	0.50 / >4.00
6	Surfers able to execute standard maneuvers consecutively. Executes advanced maneuvers on occasion.	40	0.45 / >4.00
7	Top amateur surfers able to consecutively execute advanced maneuvers.	29	0.40 / >4.00
8	Professional surfers able to consecutively execute advanced maneuvers.	27	0.35 / >4.00
9	Top 44 professional surfers able to consecutively execute advanced maneuvers.	Not reach	0.30 />4.00
10	Surfers in the future	Not reach	0.3 / >4.00

A.3.2 Breaking Intensity

Mead and Black (2001a, b, c) recognised that there is a wide range of wave shapes in the plunging category (Wiegel, 1964; Galvin, 1968; Battjes, 1974; Iribarren and Nogales, 1949). Mead and Black's (2001a, b, c) work considered wave conditions and sea floor shape, or bathymetry, of more than 40 international surf breaks. Mead and Black (2001c) showed that a plunging wave's 'vortex ratio' (after Sayce, 1997; Sayce *et al*., 1999) can be predicted using the seabed gradient. The vortex ratio is the length to width ratio of the area underneath the breaking part of the wave (Figure B-5) and indicates the 'roundness' of a wave as it breaks. As the vortex ratio approaches 1, the tube shape becomes more circular and less elongated and breaking is more intense. Breaking waves with smaller vortex ratios are more likely to collapse… Waves with vortex ratios larger than 3, are gently plunging or spilling (Mead and Borrero, 2017).

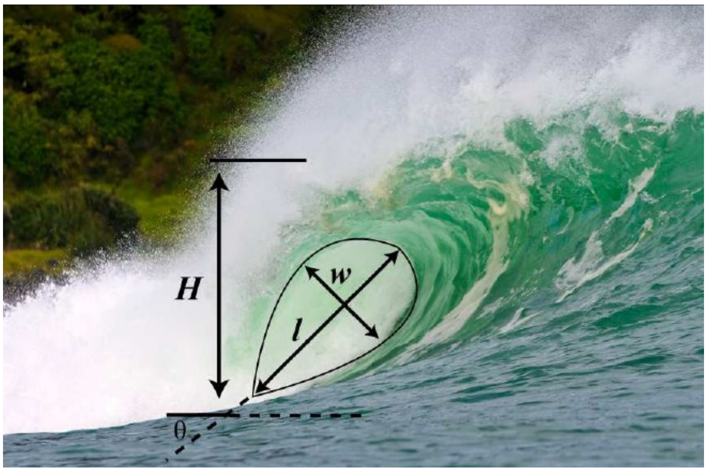


Figure B-5: Curve fitting is applied to the forward face of a crest parallel wave image and used to calculate the vortex length (l), width (w) and angle (q). H is the estimated wave height (from Mead and Borrero, 2017).

Mead and Black (2001c) showed that the orthogonal seabed gradient; which is the gradient along a wave's direction of travel, or perpendicular to the waves crest, and not the contour normal seabed gradient, is most readily applicable to predict breaking intensity. The relationship Mead and Black (2001c) established between the orthogonal seabed gradient (X) and breaking intensity (Y) is:

$$Y = 0.065X + 0.821$$

Table B-2 presents the work of Mead and Black (2001) and relates the shape of different categories of surfing waves with surfing terminology and provides examples of surf breaks fitting each breaking intensity.

Table B-2: B Breaking intensity and vortex ratio with descriptive breaking intensity terms and examples surf breaks (modified from Mead and Black, 2001c)

Intensity	Extreme	Very High	High	Medium/High	Medium
Vortex Ratio	1.6-1.9	1.91-2.2	2.21-2.5	2.51-2.8	2.81-3.1
Descriptive Terms	Square, spitting	Very hollow	Pitching, hollow	Some tube/barrel sections	Steep face, but rarely tubing
Example	Pipeline; Shark Island	Backdoor; Padang Padang	Kirra; Off-the-wall	Bells Beach; Bingin	Manu Bay; Whangamata

A.3.3 Ride length

The time that a surfer spends up and riding is incredibly important to some users, while others would rather have short wave with a very high breaking intensity. Regardless of this subjectivity, it is important to be able to measure the length of surfable waves to establish a baseline characteristic.

Consideration should be given to measuring waves both linearly and in a piecewise fashion. Historical aerial and satellite images provide the most readily accessible resource for measuring ride length. However, comprehensive characterisation from aerial and satellite images may be difficult in some locations as the number of images, and therefore points in time, may be limited; indeed, the images that are available may not have been taken at times of surfable conditions. Remote camera monitoring sites, if set up suitably can provide a large, high temporal and spatial resolution dataset that will capture all conditions. Any images need to be georeferenced and orthorectified to a reasonable degree of accuracy – sub-5 m.

The geographical position of surfers utilising GPS (the Global Positioning System) can provide a range of data products (e.g., Borrero *et al*., 2019). There are several commercially available surfing specific products as hardware (e.g., RipCurl GPS Watch, Trace, Garmin) and mobile phone apps (e.g. Waves Tracker, Surf Track) that record a surfer's position during a surfing session. The data collected from these products can be used to characterise waves that are actually surfed – as opposed to hypothetically surfable waves from (most) imagery. There are some issues associated with interpreting the GPS based data. The data is reliant on surfers being capable of completing rides that are representative of the conditions – e.g., not falling off. However, if enough data is collected, filtering methods can be used and statistical characterisation employed to 'clean up' the data (e.g., Borrero *et al*., 2019).

A combination of historical aerial and satellite imagery, remote camera images and GPS mapping of surf rides can be used to develop a comprehensive understanding of where surfers take-off, ride and finish waves at surf breaks. This information provides critical baseline data when coastal developments and activities are proposed with respect to identifying any changes that may or do occur (potential and actual impacts).

A.4 Surf Break Composition

The NZCPS describes a swell corridor as the region offshore of a surf break where ocean swell travels and transforms to a "surfable wave" (Department of Conservation, 2010). Atkin and Mead (2017) and Atkin and Greer (2019) suggest the swell corridor is an offshore extension of a Surf Break Area. Much of the work concerning swell corridors in Aotearoa New Zealand has limited a feature's extent to the Territorial Sea (Atkin *et al.*, 2015; Atkin and Mead, 2017; Atkin and Greer, 2019). This spatial restriction is based on the jurisdictional limitation of individual authorities at a regional level. The reality is, in theory, that a swell corridor can be described from the seaward edge of an SBA across an entire ocean basin, because the area offshore that influences a surf break does not stop at the edges of an SBA, nor does it stop directly adjacent to or inland from it.

This subsection introduces the functional surf break components of Mead and Black (2001b); covers the role of offshore preconditioning; and introduces the geomorphic types of surf beak and provides details on how they are created, maintained and their associated sensitivity.

A.4.1 Functional Surf Break Components

The work of Mead and Black (2001a, b) exposed a series of commonly occurring meso-scale geomorphic components from which all surfing breaks are comprised. The components are shown in Figure B-6 and named, ramp, platform, wedge, ledge, focus, ridge and pinnacle. Mead and Black (2001a) categorized the components by those which precondition the wave prior to breaking and those that break the wave (Table B-3). The functional order of components relates to their size (Figure B-7); larger offshore components align waves prior to breaking while smaller inshore components only modify a small section of the wave (Mead and Black, 2001b).

Table B-3: Functions of surfing reef components (modified from Mead and Black, 2001b).

Component	Function	Details
Ramp, Focus	Preconditioning	Modify for other components before breaking
Platform		Convey waves without change
Wedge, Ledge	Breaking	Break waves
Ridge, Pinnacle		Modify breaking waves

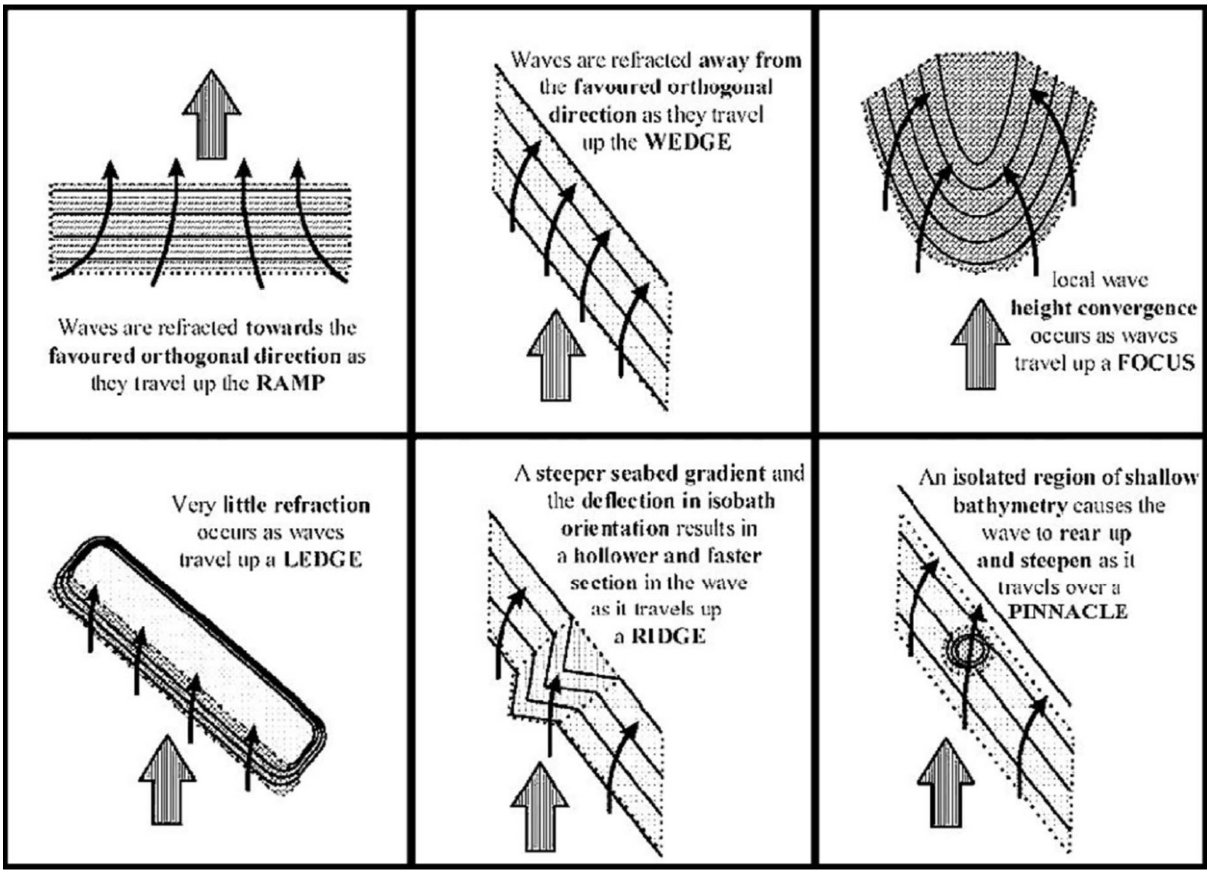


Figure B-6: Functional surf break seabed components. Isobaths of components become shallower in the direction of wave propagation (up the page). The large arrows represent the 'favoured orthogonal direction' (see Mead and Black, 2001a, b, c) and the small arrows represent the orthogonals. Note, the platform has not been included here because it is essentially a horizontal component that does not refract waves that pass over it (from Mead and Black, 2001b).

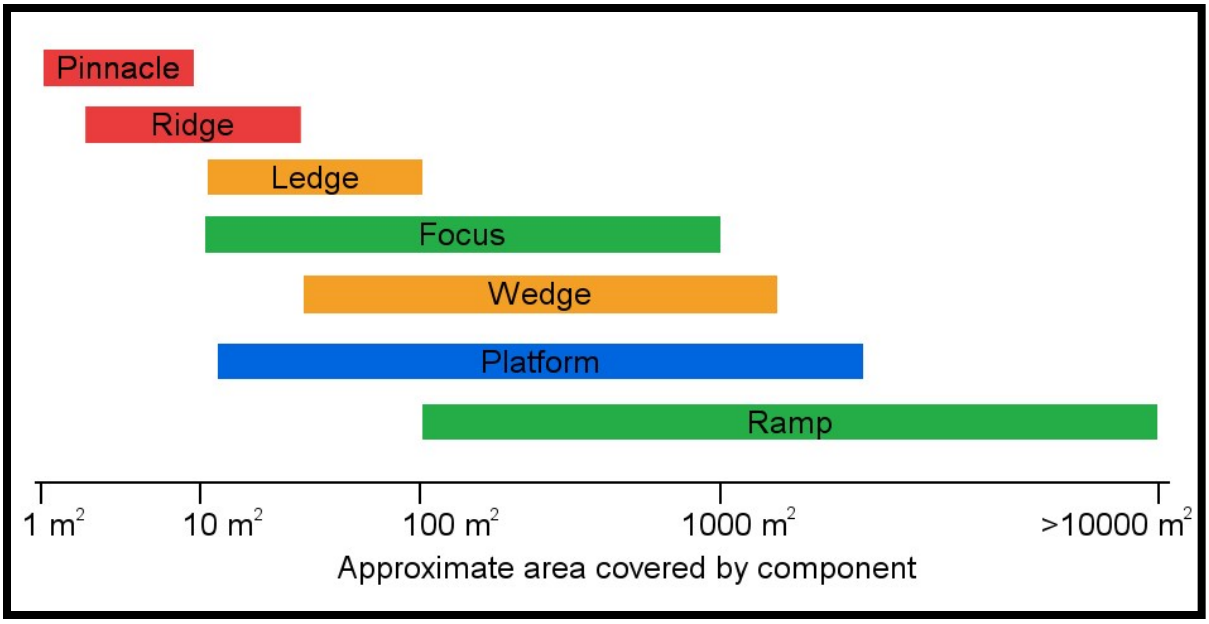


Figure B-7: The functional scales of surfing reef components (modified from Mead and Black, 2001b).

A.4.2 The Importance of Offshore Preconditioning

Atkin *et al*. (2019) propose a spectrum of preconditioning associated with the focus components; and the role of offshore features, that do not induce breaking, can range from disruptive preconditioner to focussing preconditioner. Fully focussing preconditioners have the effect of increasing wave height in their lee, and wave breaking conditions are associated with, often singular, consistent, localised peaks. Whereas a disruptive preconditioner, whilst still resulting in wave height increases, creates chaotic wave-wave interactions through extensive bifurcation of wave crests. The result is numerous, random peaks at the shore.

Both ends of this spectrum create wave height gradients which allow waves to peel in a manner conducive to surfing even when on a planar, featureless beach. Where a particular feature lies on the spectrum will be a function of incident wave conditions, relative to the size of the seabed feature and its ambient bathymetry. Preconditioning within a surf break's swell corridor can occur at significant distances (kilometres) from an SBA. Offshore ridges, sea mounts, the edges of canyons, ebb tidal deltas, large scale offshore banks, to small scale reefs can all contribute to the conditions within an SBA. The influence of these type of features often goes unaccredited, as they are not readily observed, and can be a long way from the SBA and often in relatively deep water.

Examples in Aotearoa New Zealand that depend on offshore focussing features include the Nationally Significant Aramoana and Whareakeake, which benefit from focussing and disruption across the ebb tidal delta at the entrance to Ōtākou/Otago Harbour and a dredge spoil disposal ground adjacent to Heyward Point, respectively.

A.4.3 Geomorphological Types of Surf Breaks

Mead (2000) recognised 6 geomorphic types of surf break, namely: coral reef, rocky reef, point break, rock ledge, river/estuarine delta and sand beach. Scarfe (2008) presented expanded descriptions for 5 geomorphic types, choosing to group coral reef and rocky reef together as reef breaks. Scarfe (2008) notes that there is no clear delineation between types. Indeed, it is not only possible for different surf break types to be present in a Surf Break Area, but a single surfable wave could break in association with several different geomorphological types. Furthermore, a surf break of a certain type may be reliant on a seabed feature that is not involved in the breaking of waves but is from a different geomorphic type (e.g., preconditioning from a coral atoll).

Of note is that coral reef, rocky reef, rock ledge and sand beach describe the seabed substrate, whereas point break and river/estuarine delta do not. A point break and river/estuarine could be made up of a mix of rock, boulders or sand; and a point break could be in part made up of coral reef (for example). The concise descriptions of Scarfe (2008) are modified here to provide details on formation, processes and associated sensitivity of the different break types. Examples from Aotearoa New Zealand are provided.

Point Break

Also referred to as headland break, waves refract around a point before breaking. The refraction of waves around a point filters out high frequency waves, which travel past the headland, leaving the longer period waves which are generally more conducive to good surfing conditions. A consequence of refraction is that the direction of the waves in an SBA is usually significantly different to the direction of waves offshore – however, this is not always the case.

A point or headland presents a discontinuity in a stretch of coastline and are often associated with large terrestrial outcrops (Mead and Black, 2001b). They result from being made of harder and less erodible substrate than the adjacent coastline. Whilst a headland itself maybe robust and relatively static, the coastal processes, including sediment transport around such features can be complex (Mead 2000; Phillips *et al*., 2003; Scarfe, 2008).

Point breaks are often characterized by the existence of a mobile sandy substrate, the dynamic nature of which can have an important influence on surf quality. The dependency of surfing wave quality on the sandy substrate will vary at each site. Therefore, point breaks can be considered hypersensitive. At Shipwreck Bay for instance the transgressive dune field across the headland is critical to sand supply to the break. Designating point breaks as hypersensitive could be a conservative designation for some sites, but a prudent one as the mobility of the sandy substrate is very dependent on local coastal processes at a site, and hence individual sites requires studies to determine sediment transport regimes and their relation to surfing wave quality. (e.g., Phillips *et al*., 2003; Philips, 2004).

Examples of point breaks in Aotearoa New Zealand include 10 of the 17 Surf Breaks of National Significance: Whareakeake and Karitane (Otago); Indicators, Whale Bay, Manu Bay (Waikato); {Pines, Supertubes, Mukie 2, Mukie 1}, {Peaks and Shipwreck Bay} (Northland); Stent Road (Taranaki); Makorori Point (Gisborne); and, Mangamaunu (Kaikoura).

Beach Break

At a beach break, waves break in peaks along the beach caused by offshore wave focusing and/or nearshore sand bars and rips. Successive waves can break in different locations depending on the beach morphology, offshore wave spectra (direction, height, period) and wave peakiness. Often good beach breaks have control features offshore or nearshore that stabilise the position of sand bars or dictate wave focusing.

A prerequisite of a beach break is the presence of mobile sediment. A beach break's overall natural morphology will be a function of incident wave conditions. Morphological change will be bound in part to the presence of consolidated features, such as offshore reefs, headlands and landward boundaries. By default, the presence of mobile sediment contributing to the composition of a surf break means it is a sensitive environment that can be altered very readily.

Examples in Aotearoa New Zealand include 2 of the 17 Surf Breaks of National Significance: Wainui Beach (Gisborne) and The Spit (Aramoana; Otago). Other known, truly world class beach breaks in Aotearoa New Zealand include Matakana Island (see Delta Breaks and Offshore Focussing) and an extensive list of Coromandel Beaches.

Delta Breaks

Mead (2000) refers to river/estuarine delta breaks, and Scarfe (2008) to river or estuary entrance bar breaks. Surfers often refer to this typology simply as (the) bar. The formation of material at the seaward end of a river or tidal inlet is known as an Ebb Tidal Delta (ETD). This type is therefore referred to simply as a delta break.

The ebb tidal delta is a body of sand that accumulates where outflowing estuarine or river waters and waves interact to form sand banks over which surfable waves develop. Tidal inlets are influenced by processes such as wave energy, tidal range, tidal prism, direction and rates of longshore sediment transport, sediment supply and nearshore slope, and are subject to change (Scarfe, 2008 and references there in).

The complex, dynamic nature of the ETD environments, combined with the dependence on inland/enclosed waters, which can be subject to all manner of external factors, which are not necessarily associated with nearshore processes, means that delta breaks are considered to be ultrasensitive.

Examples in Aotearoa New Zealand include 3 of the 17 Surf Breaks of National Significance: Karitane (Otago), Waiwhakaiho (Taranaki) and Whangamata (Waikato). Other high-quality delta breaks in Aotearoa New Zealand include Okiwi Bar (Great Barrier Island) and Whakatane Heads (Bay of Plenty). A case could be put forward for a site such as Matakana Island as a delta break, where waves are pre-conditioned by a very large ebb tidal delta, but not broken on or near the pro delta slope. The result is improved surfing conditions inshore. This is discussed in Offshore Focussing.

Reef Breaks

Many highly regarded surf breaks are reef breaks. This is because the consolidated material of a reef provides consistent wave breaking patterns. The consolidated material can also provide steeper seabed gradients than those possible with unconsolidated material (e.g., angle of repose), often resulting in waves that break with a high intensity. Mead (2000) refers to both coral and rocky reefs. Coral reefs are not found in Aotearoa New Zealand[10], but there are plenty of rocky reefs. The formation of surfable reef breaks can be from numerous processes. In the tropics, coral reef surf breaks can be offshore, isolated, intertidal seabed features with footprints and shapes ideal for surfing (e.g., Cloudbreak - Fiji); other coral reef surf breaks will have been modified by freshwater streams that “cut” sections of reef away creating discontinuities in the coastline (e.g. Teahupoʻo - French Polynesia).

Rocky reefs for surfing are often the convenient result of geological processes, and rocky reef breaks are often associated with an outcrop. Reef breaks are similar to point breaks, except, in general, there is no extensive subaerial land mass, and the processes of refraction compensation, low-pass filtering and crest-straightening are not so apparent, if at all; which is a result of the orientation of geomorphic components to incident wave crests.

Both rocky and coral reef surf breaks are made up of consolidated material which makes them relatively robust in some respects. In Aotearoa New Zealand, rocky reef surf breaks can be considered robust in terms of physical coastal processes. Examples are Tuamoto Island in Gisborne and Papatowai in the Catlins, both Surf Breaks of National Significance. Other regionally significant examples in Aotearoa New Zealand include Daniel’s Reef, Goat Island, Kuaotunu and the many high quality reef breaks along Taranaki’s Surf Highway 45.

Ledge Breaks

In the surfing community, ledge breaks are often referred to as a “slab”. While no particular origin to this idiom can be identified, it is assumed the term slab refers to the relatively flat,

[10] Note, coral communities are found in Aotearoa New Zealand, but they do not form reef structures suitable for surfing

tabletop like appearance of inshore reef structure. Ledges share many of the attributes of a rocky reef break.

Scarfe (2008) states that steep rock ledges interrupt wave propagation, although this is essentially true of all surf breaks, and coastlines in general. Scarfe (2008) also states that waves come from relatively deep water into very shallow water, modifying the way that the waves break, which is a better description of the sharp seabed transition caused by ledge breaks.

It should be noted that a ledge is also a functional surf break component (Mead and Black, 2001a); and that ledges are readily seen as part of functional component configuration (Mead and Black, 2001b). Wave breaking shape associated with ledge breaks and sections is one of very high intensity (Mead and Black, 2001c), with many globally recognised slabs pushing the boundary from plunging to collapsing. When considering a standalone ledge break, the difficulty and dangers associated with surfing this type means that they are utilised by the few and will often fall into category of secret spot. It is for this reason that no known slab locations are provided here.

Aotearoa New Zealand examples of where a ledge makes up part of a surf break composition are the Nationally Significant Manu Bay – “The Ledge” (Waikato), and Takapuna Reef (Auckland; Mead and Black, 2001b)

A.5 Other Physical Factors

A.5.1 Wave Parameters

Height

Atkin and Greer (2019; after Atkin and Mead, 2017) discuss wave height for surfable conditions in the context of numerical modelling, where thousands of wave conditions are simulated and a suitable threshold to filter the conditions was required. The value used of 0.75 m and was reached by evaluating a range of largely grey literature. In detailed characterisation, minimum wave height for a surf break to become surfable must be evaluated on a case by case basis, since there are a variety of factors that may make a break surfable at smaller or larger wave heights than 0.75 m.

There are some breaks, such as featureless, planar beaches ideal for learning – nursery breaks, which may be surfable in very, very small wave heights. There are other breaks, especially big wave spots where the wave breaking zone has to be a certain distance from shore for the surf break to be safely navigated (e.g. Jardim Do Mar, Madeira), or simply the wave has to be large enough for the wave orbitals to 'feel' deep seabed features that compose the surf break, and require ocean swell several meters height before they are considered surfable. Other surf breaks 'max out' if the wave heights are too large.

Period

Waves with periods of 20 seconds begins to feel the seabed at the edge of the continental shelf (200 m deep) and so begin to change direction and focus/de-focus (through the processes of refraction/diffraction) often 10's of kilometres offshore. Waves with periods of 10 seconds will begin to feel the seabed and start refracting until the water depth is 55 m.

As a result, period can limit how much wave energy is delivered to a surf break. Long period swell can refract into breaks that are orientated more than 180° away from the offshore direction of the swell, although short period swell cannot. A good example of this effect is at Ahipara on the west coast in the far North Island. Here the breaks are orientated to the northeast, which is 180° around the headland from the direction of the southwest swell, and no matter how large the waves are on the open coast, if they do not have long enough period, they simply pass by up the coast without refracting into Ahipara.

Low period waves will refract less than high period waves, and the result will be a filtering or cleaning (Mead, 2000) of the wave spectra. For the coral reef break of Restaurants in Fiji, the complex bathymetry offshore can result in high wave period swells not propagating into the SBA as readily as lower period waves.

Wave period has an effect on the surfing experience with longer wave periods delivering higher breaking intensities often providing more powerful, ‘heavy’ and exciting conditions with steep and/or hollow wave faces. Short period swells are often termed ‘fat’ by surfers because they lack power/breaking intensity and have less-steep faces making it more difficult for participants to execute certain manoeuvres or progress through certain sections.

This is reflected in the Iribarren number, where wave length is incorporated into the calculation (see Section 2), where wave height (H) over wave length (L) is included; H/L is the wave ‘steepness’ parameter, which is counter intuitive to a surfer, since ‘steeper’ waves have shorter wave lengths/periods and so have less steep wave faces than less ‘steep’ (longer wavelength/period) waves. This is further complicated by the wave height also effecting the breaking intensity of waves, which can be simply explained as “for a particular wavelength/period, as the wave height increases, the breaking intensity decreases”.

Direction

Wave direction is interesting when considered in terms of a surf break, particularly when considering dendritic coastlines and/or distant wave generation sources. Surfers will regularly consider the direction of offshore waves at a regional or national scale, some consider the general direction of the generating source, such as a cyclone tracking south into the Pacific Ocean from the tropics. Like the cyclone, swell direction is constantly changing in time, but may be characterised. Indeed, some surf breaks require certain swell directions, others will work on a wide range of swell direction, but the quality of surfing waves can change.

Characterising a surf break in terms of wave direction is complex and requires consideration of wave directions at multiple points in both space and time, from generation source through to the SBA. The requirement for this holistic view is particularly evident at SBA’s associated with headlands and peninsulas where wave direction can be significantly different depending on whereabouts it is examined.

A.5.2 Wind

Winds play an important role in both generating and grooming waves for surfing. The best surfing waves are long period waves generated by winds in distant locations. Local winds can play an important role in creating or destroying surfing waves (Pratte *et al*. 1989). The ideal wind is light to non-existent for the cleanest conditions.

When considering winds for surfing, the direction is relevant to wave crest. Despite this relevance, the terms used to describe wind directions in surfing are relevant to the shoreline, which can be parallel to the wave crest, but not in all cases. A wind that blows directly offshore (perpendicular) is conducive to clean conditions and can allow the wave to steepen by delaying breaking. A light offshore wind is also said to groom the wave face to make it smoother (Schrope, 2006). Very strong offshore winds can make the waves difficult to catch, even blow the rider off the back of a wave.

Onshore and cross shore winds can ruffle the water surface. These wind directions can introduce high frequency signals to the surfing area, which along with white capping can encourage the onset of wave breaking, which can occur randomly. The result is often undesirable sections that reduce the overall length of the surfable wave. The traditional view of onshore and cross shore winds has been that they are unwanted. However, there has been a shift in the performance level of surfing with one of the most advance manoeuvres, the aerial, benefiting directly from the surfing conditions provided by onshore or cross shore winds. Indeed, advanced surfers, particularly those who surf in a competitive capacity, will target certain wind conditions to train for specific manoeuvres.

There are some surf breaks that are utterly dependent on the wind having blown onshore to create a surfable wave, and when the wind changes direction of subsides the waves follow suit. This often occurs in sheltered and fetch limited areas, such as channels and lakes. A prime example in Aotearoa New Zealand is the Firth of Thames where there are several point breaks and delta breaks that rely on the short wavelength wind waves driven by northly winds. Titahi Bay in Porirua is also a good example, where strong northerlies generate waves and the winds often swing suddenly to the south and quickly clean up the surfing conditions.

In terms of defining a surf break, wind strength and direction are not limiting factors. They can affect the experience, with many participants preferring clean and calm conditions, however if the wave height is large enough to surf, the local wind conditions are ultimately irrelevant (Atkin and Mead, 2017; Atkin and Greer, 2019).

A.5.3 Tides and Currents

This section is concerned with how tides and currents effect surfing waves directly. This section does not consider the complex processes of how tides and currents effect seabed morphology in detail. The tides result in modulation of both water level and currents. Non-tidal currents to consider are those driven by rivers and by the waves themselves (i.e., rip currents).

Water level

As described in Section 2, the processes of wave propagation, refraction and breaking are tightly linked with seabed shape and wavelength. Changes in water level can alter the way in which a surf break functions on a range of scales.

If wave height, period and direction are constant, and wave direction is oblique to depth isobaths, then a lower water level (i.e., low tide) will invoke a greater degree of refraction than a higher water level (i.e. high tide). The result can be that more wave energy is delivered to an SBA (see Section 5.1). Conversely, if an offshore feature, such as a submerged breakwater, bar or coral reef dissipates or redirects wave energy, the influence of the feature will be less at a higher water level and more wave energy can be delivered to an SBA.

Tidal modulation of surfing wave quality within an SBA itself is a frequently discussed topic for surfing enthusiasts. The changes in water level can result in large horizontal changes in the breaking position, with breaking possibly occurring on very different seabed features between high and low tide. The result is that surf breaks become known for working best on a specific tidal phase (e.g. high, low, mid, dropping, rising, etc.), however this designation is very subjective as it is down to user requirements and preference.

There are other phenomena associated with tides that are known by surfers, but not well understood scientifically. For example, the ‘mid-tide push’ is known of on open coasts worldwide and there are data to confirm the occurrence of an increase in wave height during the mid-incoming tidal phase along some coasts. However, why this occurs is unknown, although it is expected that it may in part be due to interaction between the shore-parallel tidal currents and wave propagation which is more shore-normal.

Currents

Surfers utilise rips to make paddling back to the take-off zone easier. At river mouths and delta breaks, outgoing flows will assist in quickly transporting a surfer further offshore. This can in fact can become quite hazardous with currents overpowering surfers and moving them away from a desired position.

Where current direction opposes wave direction, wavelength will tend to decrease (period remains constant), and wave height will increase. The result is often waves with steeper (than usual) faces. This can be quite sought after by some surfers, much like particular water levels. However, these counter currents can also lead to less desirable conditions by making the surface and face of the wave choppy and making it difficult for surfers to maintain position. Yet, it is these currents that contribute to maintaining the seabed features that break the waves in a manner that is conducive to surfing. At delta breaks the currents, in a dynamic equilibrium with waves, will shape the ebb tidal delta; where rip-currents are persistent on open beach breaks they help to maintain the adjacent sand bar.

The effects of tidal currents on wave height at surf breaks is not well understood, however, such impacts need to be considered when characterising a surfing break. An important feature of the surf along the western coast of the Firth of Thames is the effect of the tidal current on wave height and direction (and likely wave directional spreading). This is likely similar to the phenomena that occurs along the Florida coast due to wave/current interactions with the Gulf Stream (e.g. Wang *et al*., 1994) where, the offshore location of the Gulf Stream can greatly affect wave heights at the coast).

Surfers that frequent the western Firth of Thames are aware of this phenomenon (which is sometimes described as reflection off the eastern coast of the Firth, although this is not likely to be physically possible). The importance and magnitude of this kind effect can only be tested through well designed measurement.

An interesting aspect of the effects of tidal height and tidal currents is that tides are mostly driven by the moon, with spring tides occurring at full and new moons (i.e. larger tidal ranges and consequent larger tidal currents). An often-postulated phenomenon is that new swells arrive with the full and new moon. But the moon has no impact on the generation of waves, so this is not likely. However, the spring tides that occur during full and new moons do increase the tidal levels and tidal current speeds, which in turn can have the effect of delivering waves into breaks and focussing wave energy and increasing wave heights at some breaks. In locations where there are strong tidal currents, “full moon swells” are well known (e.g. parts of Indonesia).

A.5.4 Natural Variability and Sensitivity

Surfers say that one of the factors that makes surfing such a challenging and interesting activity is that “no two waves are the same”. This natural variability in wave quality results from any combination of factors including variations in the wave height, period, direction, directional spread, all along with the state of the tide. The factors controlling wave quality can change at seasonal or monthly time scales as when weather events pass through, within a day to hours as swells rise and drop to within minutes to hours as the wind direction changes and the tide rises and falls.

Less obvious is the role that mobile sediments on the sea floor make to the natural variability of a surf break. The movement of seabed material and incident wave conditions is a constant feedback loop with each influencing the other. The most readily observed is the annual change from summer to winter profiles (Wright and Short, 1984)

The introduction of tidally driven currents, riverine input and wind driven sand transport makes for a consistently changing environment. Point breaks and particularly reef breaks, where the seabed is potentially less mobile, may exhibit less natural variation and more consistent wave quality for surfing. However, Phillips and Mead (2008) showed that large changes to the seabed offshore from sand moving along the coast or around headlands can have profound effects on surfing wave quality.

Sensitivity, or the robustness of a surf break to change is a function of the relative complexity of processes and forces maintaining surfable conditions. On top of the seabed configuration, the factors that need to be considered regarding sensitivity are:

- Incident wave climate and exposure.
- Tides and associated currents.
- Sediment transport pathways (including aeolian).

Management considerations:

- Surf breaks located on exposed, high-energy coastlines may be, relatively, more robust.
- Surf breaks that rely on sediment transport to maintain surfing wave quality, such as beach breaks, delta breaks and some point breaks will tend to be more sensitive than consolidated rocky reefs.
- Surf breaks located proximal to enclosed waters and waterways, occurring in and around tidal inlets may well be ultrasensitive to change.

A.6 References

Atkin, 2010. The Impact of an ASR on Breaking Wave Conditions at Boscombe, UK. Thesis: University of Southampton, UK.

Atkin, E.A and Greer D., 2019. A Comparison of Methods for Defining a Surf Break's Swell Corridor. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.

Atkin, E.A. and Mead, S.T., 2017. Surf Breaks of Regional Significance in The Waikato Region. Waikato Regional Council Technical Report 2017/19. 64pp.

Atkin, E. A., Gunson, M. and Mead. S. T., 2015. Regionally Significant Surf breaks in the Greater Wellington Region. eCoast technical report for Greater Wellington Regional Council.

Atkin, E.A., Mead, S.T. and Phillips, 2019. Preliminary Investigations of Offshore Wave Preconditioning. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 78–90. Coconut Creek (Florida), ISSN 0749-0208.

Atkin, E., and S. T. Mead, 2011. Literature Review and a Preliminary Investigation of Offshore Focussing Reefs. Prepared for Unitec Institute of Technology, August 2011.

Battjes, J. A., 1974. Surf Similarity. Proc. 14th Coastal Engineering Conference. ACSE p.466-480.

Borrero, J.C.; O'Day, C., and Rifai, J., 2019. Application of Rip Curl Searchgps Watch Data for Analysing Surf Breaks. In: Bryan, K.R. and Atkin, E. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 55–69. Coconut Creek (Florida), ISSN 0749-0208.

Butt, T. and Russel, P., 2002. Surf Science: An Introduction to Waves for Surfing. Penzance: Alison Hodge.

Department of Conservation, 2010. New Zealand Coastal Policy Statement 2010. Wellington: Department of Conservation.

Galvin, C. J., 1968. Breaker Type Classification on Three Laboratory Beaches. Journal of Geophysical Research 73, 3651-3659.

Hutt, J. A., Black, K. P. and Mead, S. T., 2001. Classification of Surf Breaks in Relation to Surfing Skill. In: Black, K.P. (ed.) Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research, Special Issue No. 29, pp. 66-81.

Iribarren, C. R., and Nogales, C., 1949. Protection des Ports. Section II, Comm. 4, XVIIth Inter. Naval Cong., 31-80.

Kelly, J., 1973. Surf parameters: Final report part II: Social and historical dimensions. Honolulu: University of Hawaii James K. K. Look Laboratory of Oceanographic Engineering.

Mead, S. T., 2000. Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs. PhD thesis, University of Waikato, New Zealand. Pp 209 + appendices.

Mead, S. T., Atkin, E.A., and Phillips, D., 2012. Design Optimization of Offshore Focusing MPR's, ASBPA 2012 National Coastal Conference. San Diego, October 2012.

Mead, S. T. and Black, K. P., 2001a. Field Studies Leading to the Bathymetric Classification of World-Class Surfing Breaks. Journal of Coastal Research, Special Issue No. 29, pp. 5-21.

Mead, S. T. and Black, K. P., 2001b. Functional Component Configurations Controlling Surfing Wave Quality at World-Class Surfing Breaks. Journal of Coastal Research, Special Issue No. 29, pp. 22-32.

Mead S. T. and Black, K. P., 2001c. Predicting the Breaking Intensity of Surfing waves. Journal of Coastal Research, Special Issue No. 29, pp. 51-65.

Mead, S.T. and Borrero, J., 2017. Surf Science and Multipurpose Reefs. In Green, D.R. and Payne, J.L. (Eds.), Marine and Coastal Resource Management: Principals and Practice. (pp. 288–311). Abingdon: Routledge.

Moores, A., 2001. Using Video Images to Quantify Wave Sections and Surfer Parameters. MSc Thesis: University of Waikato, New Zealand.

Philips, D., 2004. Sediment Dynamics of a Shallow Exposed Surfing Headland. PhD thesis, University of Waikato, New Zealand.

Philips, D., Black, K. and Healy, T., 2003. Sandy Seafloor Volume Changes Off a High Energy Headland Boulder Beach, Raglan, New Zealand, Coasts and Ports Australasian Conference 2003.

Phillips, D.J. and S.T. Mead, 2008. Investigation of a Large Offshore Sandbar at Raglan, New Zealand: Impacts on Surfing Amenity. Shore and Beach Vol 76(2) Spring 2008

Pratte, T.P., Walker, J.R., Gadd, P.E. and Leidersdorf, C.B., 1989. A new wave on the horizon: towards building surfing reefs nearshore. In: Proceedings for Coastal Zone '89 (Charleston, South Carolina), pp. 3403–3411.

Sayce, A.J., 1997. Transformation of Surfing Waves Over Steep and Complex Reefs. MSc thesis, University of Waikato, New Zealand.

Sayce, A.J., Black, K.P., and Gorman, R., 1999. Breaking Wave Shape on Surfing Reefs. Proceedings Coasts and Ports '99, Vol. 2, 596-603.

Scarfe, B., 2008. Oceanographic Considerations for the Management and Protection of Surfing Breaks. PhD thesis, University of Waikato, New Zealand.

Schrope, M., 2006. Oceanography: creating the perfect wave. Nature 444, 7122:997–999.

van Ettinger, E., 2005. Artificial Surf Reef Design: Dutch Swell Conditions. MSc Thesis, Delft University of Technology, Netherlands.

Walker, J.R., Palmer, R.Q. and Kukea, J.K., 1972. Recreational Surfing on Hawaiian Reefs. Proceedings of the 13th Coastal Engineering Conference.

Wang, D.W., Liu, A.K., Peng, C.Y. and Meindl, E.A., 1994. Wave-current interaction near the Gulf Stream during the Surface Wave Dynamics Experiment. Journal of Geophysical Research: Oceans, 99(C3), pp.5065-5079.

Wiegel, R. L., 1964. Oceanographical Engineering. N.J: Prentice-Hall.

Wright, L.D. and Short, A.D., 1984. Morphodynamic Variability of Surf Zones and Beaches. Marine Geology. 56, 93–118.

Appendix B. **Surfing Resource**

B.1 Introduction

Orchard *et al*. (2019; after Orchard, 2017) provides a review of the regional significance concept that has evolved from New Zealand's world leading recognition of surf breaks in policy. Policy 16 of The New Zealand Coastal Policy Statement 2010 describes a surf break as:

> *A natural feature that is comprised of swell, currents, water levels, seabed morphology, and wind. The hydrodynamic character of the ocean (swell, currents and water levels) combines with the seabed morphology and winds to give rise to a* ***'surfable wave'****. A surf break includes the* ***'swell corridor'*** *through which the swell travels, and the morphology of the seabed of that wave corridor, through to the point where waves created by the swell dissipate and become non-surfable.* ***'Swell corridor'*** *means the region offshore of the surf breaks where ocean swell travels and transforms to a* ***'surfable wave'****.* ***'Surfable wave'*** *means a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the wave crest.*

It is widely recognised that a surf break is much more than just a physical feature. Surf breaks have a long social history and a strong associated culture (Kelly 1973; Skellern *et al*. 2013). A surfing resource includes not only the surf break but aspects that make it a natural and social resource. Here the fundamental attributes that contribute to a surfing resource are described (after of Orchard *et al*., 2019), in alphabetical order. The physical process attributes have not been included.

B.2 Primary Attributes

Amenity value

A surf break has direct amenity value by providing a resource for recreational activities. Surf breaks provide amenity value as focal point for other amenities, so the value extends to onlookers (e.g., Peryman and Orchard, 2013). Orchard (2017) considers the pleasantness of the location including aesthetic aspects such as the beauty or memorability of a location. With increased popularity comes improved access and facilities. Negative impacts on surfing amenity may impact not just on surfers but also visitors, the local community and businesses (Lazarow *et al*., 2008).

Economic value

At a local level surf-related tourism can be the corner stone of many coastal communities, with everything from accommodation to local mechanics benefitting from the quasi-ephemeral boost in population. Surf based industries benefit directly, with surf schools/lessons catering for the masses or individuals, and surf shops supplying hardware, equipment and branded apparel. Surfing is associated with lifestyle and as such is used as a marketing tool for anything from beverages to credit cards. A significant monetary value associated with surfing resources is real estate. Neubauer (2006) showed relationships between distance to a surf break and house price in New Zealand (shorter distance = higher price), with higher quality waves accentuating the relationship. McGregor and Wills (2016) attribute increases in property prices and rental costs to tourism associated with surfing resources. Scorse *et al*. (2015) show that at Santa Cruz proximity to a surfing resource is a statistically significant contributor to overall home value, and that houses are on average US$106,000 more valuable than an equivalent home a mile away.

The economic value of a surf break is a useful and easy to understand statistic for non-surfers and is frequently the starting point for negotiations when considering the effects of coastal developments or activities. However, putting a dollar value on a surfing resource is difficult because while studies have shown that a single surf break can be responsible for generating millions of dollars per annum, a price cannot be put on certain of the value categories (e.g. sense of wellbeing). Studies of “surfonomics” provide a range of techniques and methodologies to capture the non-market values and wider economic impacts and significance of the sport of surfing (Scorse and Hodges, 2017).

Education

Appendix A provides details on the differences between particular surf breaks and the requirements of different users. Some surf breaks may be of a low performance value to skilled surfers but extremely valuable to learner surfers (e.g. a "nursery break"). Other breaks will provide specific wave breaking conditions for the development of young competitors. Beyond performance though, surf breaks provide a focal point for confidence building and encourage people to participate and socialise in a supportive environment.

Historic, heritage, and cultural associations

Policy 1 of the New Zealand Coastal Policy Statement recognises the cultural and historic heritage in the coastal marine area. Surf breaks are focal points for historical and heritage values. Across Aotearoa New Zealand there are numerous, long standing board riding and surf lifesaving clubs. Aotearoa New Zealand has numerous surfing competitions, some of which are open to international competitors. Orchard *et al*. (2019) also state the importance to contemporary coastal culture, the contribution to the local sense of place, and tangata whenua values associated with the surf break.

Policy 2 of the New Zealand Coastal Policy Statement recognises that tangata whenua have traditional and continuing cultural relationships with areas of the coastal environment. Waiti and Awatere (2019) identify these cultural relationships amongst kaihekengaru (Māori surfers') and their importance for creating a sense of place that is underpinned by a Māori worldview.

Level of use

This attribute recognises the regularity with which people choose to use a surf break, and also considers the numbers that use it; these two aspects are not mutually exclusive. For example, a particular surf break may not be surfable under many conditions, but when conditions are surfable it is used by many surfers. This attribute also accounts the diversity of users and the different types of watercraft used there.

Naturalness

Recognises the degree to which the surf break is free from modifications to the natural environment e.g., in relation to the presence of particular flora and fauna, and absence of man-made structures and pollutants (Orchard *et al*., 2019).

Rarity

This considers a surf break's utility within a geographical boundary. There are a range of surf breaks based on geomorphology (Mead 2000; Scarfe, 2008; Appendix A). However even different surf break types can deliver different surfing conditions and therefore experience. A surf break can be considered in terms of suitability for different participants of surfing e.g., learners, big wave surfers, long boarders, body boarders etc. A surf breaks rarity should also be considered in the context of all other fundamental attributes (e.g. a coastline with plentiful surf breaks but one with an outstanding fundamental attribute(s) out of character with the region). Papatowai was considered by the NZCPS board of Enquiry to be a Surf Break of National Significance because of its recognition as one of Aotearoa New Zealand's few big wave surfing venues.

Uniqueness

This attribute also considers a surf break's utility within a geographical boundary. This considers a surf breaks usability at times when all other breaks are unsurfable. It may be a surf break that picks up all available wave conditions while at other surf breaks the waves are too small to surf; or it may be offshore when all other surf breaks experience onshore winds (see Appendix A). This attribute considers the relationships between surf breaks in different weather and swell conditions.

Wilderness value

This attribute is synonymous with a subcategory of Surf Breaks of Local Significance and 'secret spots' which are perceived as being known to a few, closely guarded and/or challenging to access (Atkin, 2017; Atkin and Mead, 2017). Wilderness value transcends these secret spot associations with the level of remoteness and/or isolation being important. One appeal of high wilderness value is the, expected, lower number of users, which is a function of knowledge but also the commitment required to access a location.

B.3 Community Values

Peryman and Orchard (2013) evaluated major categories of value associated with surf breaks from the perspective of the coastal communities from Gisborne (Peryman, 2011a) and the Bay of Plenty (Peryman, 2011b). Table C-1, adapted from Orchard *et al*. (2019), presents these categories with contributing aspects to provide background.

Surfing resources play a key role in many coastal societies by facilitating social interactions and experiences associated with a high quality of life. For Boardriders clubs the surfing resource is the focal point of their activities and the social platform is very broad, with internal and external competition, team building, and family contributions and activities; across a full range of age groups.

Some users associate surfing resources with spirituality and a sense of wellbeing; others simply with a livelihood that directly draws from the well reported economic benefits of surfing resources in the coastal environment (Lazarow *et al*., 2009; Nelsen *et al*., 2007; Nelsen *et al*., 2013). Hales *et al*. (2017) describe the term “Surfing Capital” as the four factors which shape the surfing experience being: 1) the physical features of and surfer’s awareness of, the quality of waves for surfing, 2) the frequency of quality waves, 3) the coastal and marine environment and 4) socio-cultural issues that are associated with coastal places.

Table C-1. Categories of value associated with surf breaks identified from community surveys in the Bay of Plenty and Gisborne regions. Adapted from Orchard *et al*. (2019).

Theme	Value categories	Contributing aspects
Social	Physical and mental health benefits	Surf breaks are host to many user groups who participate in many different forms of recreation with positive qualities for physical and mental health for people of all ages and walks of life
	Educational value	Surf breaks are venues for skills learning, including encouragement of young / learner surfers to participate, hold contests, and socialise in a supportive environment
	Enabling social interactions	Surf breaks support a diverse range of interactions that contribute to a social fabric that extends into wider communities
	Lifestyle value	Surf breaks contribute to healthy, family-orientated and community-based lifestyles
	Spiritual value	Surf breaks are a source of spiritual energy and a place to exercise spirituality important to individual health and community well-being
	Experiential and amenity values	Surf breaks contribute to scenic and naturalness values important to recreational users, onlookers, coastal inhabitants and visitors
		Surf breaks contribute to visual and oral expressions of place – interconnected to wider landscape and seascape values
		Surf breaks contribute to the nature and memorability of experiences in the coastal environment
		Raw and undeveloped natural landscapes and seascapes contribute to the opportunities for wilderness experiences
		Built access and facilities can contribute to surf break amenity though are not always desirable
Cultural	Cultural use and enjoyment	Access to, use and enjoyment of surf breaks are important aspects of the link between coastal culture and surf break environments
	Places of cultural significance	Many surf breaks are associated with important cultural or heritage associations and some are considered 'sacred treasures'
Economic	Commercial activities and economic effects associated with surf breaks	Surf-related tourism and surfing industry activities are important to local, regional and national economies.
		Surfing is extensively used in the marketing and promotional activities and contributes to the branding of many commercial products as well as visitor and lifestyle destination
		The contribution of surfing to healthy lifestyles has physical and mental health benefits that contribute to economic considerations
Environmental	Natural features and life-supporting systems	A range of physical aspects of the both terrestrial and aquatic environment contribute to the existence, character, and uniqueness of surf breaks
		The ecology and ecological health of surf breaks, adjacent areas, and upstream catchments can influence use and enjoyment
		Surf breaks have environmental educational value as sites for experiencing aspects of the coastal environment

B.4 References

Atkin, E. A., 2017. Known Surfing Coastlines in the Waikato Region. eCoast Letter Report for Waikato Regional Council.

Atkin, E.A. and Mead, S.T., 2017. Surf Breaks of Regional Significance in the Waikato Region. Raglan: eCoast Marine Consulting and Research.

Hales, R., Ware, D.; Lazarow, N. 2017. Surfers and public sphere protest. Pp 125-136 in Bourne G. and Ponting, J. (Eds) 2017 Sustainable Surfing. Routledge London and New York, 261p.

Kelly, J., 1973. Surf parameters: Final report part II: Social and historical dimensions. Honolulu: University of Hawaii James K. K. Look Laboratory of Oceanographic Engineering.

Lazarow, N., Miller, M.L. and Blackwell, B., 2008. The value of recreational surfing to society. Tourism in Marine Environments, 5(2-3), pp.145-158.

McGregor, T. and Wills, S., 2016. Natural Assets: Surfing a wave of economic growth. Economics Working Papers Series, 6.

Mead, S. T., 2000. Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs. PhD Thesis, University of Waikato, New Zealand. 209p + appendices.

Nelsen, C., Cummins, A., and Tagholm, H., 2013. Paradise Lost: Threatened Waves and the need for Global Surf Protection. Journal of Coastal Research, 65(sp1), 904-908.

Nelsen, C., Pendleton, L., and Vaughn, R., 2007. A socioeconomic study of surfers at Trestles Beach. Shore and Beach, 75(4), 32–37.

Neubauer, T., 2006. How proximity to a high quality Surfbreak affects Land and Property Values. Technical Study ASR Ltd.

Orchard, S., 2017. Regional significance criteria for the assessment of surf breaks. Report prepared for Taranaki Regional Council. 27p.

Orchard, S., Atkin, E.A. and Mead, S.T., 2019. Development of the Regional Significance Concept for Surf Break Management in Aotearoa New Zealand. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 23–34. Coconut Creek (Florida), ISSN 0749-0208.

Peryman, B., 2011a. Bay of Plenty Surf Break Study. Technical Report for Bay of Plenty Regional Council.

Peryman, B., 2011b. Surf Break Identification and Protection in the Gisborne District. Technical Report for Gisborne District Council.

Peryman, P. B., and Orchard, S., 2013. Understanding the Values and Management Needs of New Zealand Surf Breaks. Lincoln Planning Review, 4(2).

Scarfe, B., 2008. Oceanographic Considerations for the Management and Protection of Surfing Breaks. Doctor of Philosophy, University of Waikato, New Zealand.

Scorse, J. and Hodges, T., 2017. The non-market value of surfing and its body policy implications. Pp 137-143 in Bourne G. and Ponting, J. (Eds) 2017 Sustainable Surfing. Routledge London and New York, 261p.

Scorse, J., Reynolds III, F. and Sackett, A., 2015. Impact of Surf Breaks on Home Prices in Santa Cruz, CA. Tourism Economics, 21(2), pp.409-418.

Skellern, M., Peryman, B., Orchard, S., and Rennie, H., 2013. Planning approaches for the management of surf breaks in New Zealand. Report prepared for Auckland Council, Bay of Plenty Regional Council and Surfbreak Protection Society, December 2013. 98p.

Waiti, J. and Awatere, S., 2019. Kaihekengaru: Māori Surfers' and a Sense of Place. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 35–43. Coconut Creek (Florida), ISSN 0749-0208.

Appendix C. **Engagement with Māori**

The following links provide resources on appropriate and meaningful methods for engaging with local iwi. While these resources are mostly aimed at Council use, the underlying principles and methods are applicable for developers. The resources consider our collective obligations under the Treaty of Waitangi, Resource Management Act 1991 and New Zealand Coastal Policy Statement 2010.

Auckland Regional Council: Lessons for successful Mana Whenua engagement

http://knowledgeauckland.org.nz/assets/publications/Lessons-for-successful-Mana-Whenua-engagement-FINAL-WEB.pdf

Bay of Plenty: Iwi Resource Management and Engaging with Māori

https://www.boprc.govt.nz/plans-policies-and-resources/policies/operative-regional-policy-statement/rps-implementation-strategy/iwi-resource-management/

https://www.boprc.govt.nz/media/717746/engagement-toolkit.pdf

Waikato Regional Council: Māori Engagement Framework

https://www.waikatoregion.govt.nz/assets/WRC/Council/Policy-and-Plans/11340016-Maori-Engagement-Framework-Guide.pdf

Department of Conservation: New Zealand Coastal Policy Statement – Policy 2

https://www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/new-zealand-coastal-policy-statement/new-zealand-coastal-policy-statement-2010/policy-2-the-treaty-of-waitangi-tangata-whenua-and-maori/

The Ministry for the Environment: Effective participation in resource consent processes: A guide for tangata whenua and Mana Whakahono ā Rohe guidance

http://www.mfe.govt.nz/publications/rma/effective-participation-resource-consent-processes-guide-tangata-whenua

http://www.mfe.govt.nz/publications/rma/mana-whakahono-%C4%81-rohe-guidance

Inspiring Communities

http://inspiringcommunities.org.nz/wp-content/uploads/2018/01/Working-with-Tangata-Whenua_IC_2018.pdf

Cultural Impact Assessment examples:

Rena Long-Term Environmental Recovery

Pukekohe Wastewater Discharge Application

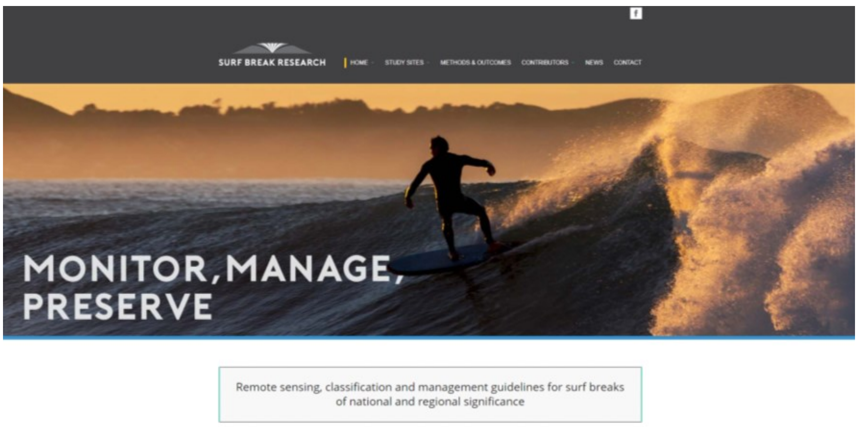
Appendix D. **Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance**

In 2015 the University of Waikato, Hume Consulting Ltd and eCoast formed a collaboration to address a knowledge gap in the management of surfing resources. “Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance” was a 3-year, Ministry for Business, Innovation and Employment funded project under the targeted research investment mechanism, and Enhanced Environmental Decision Making and Behaviour Change Investment Priority.

The project considered natural resources around the coast of Aotearoa New Zealand that are publicly accessible to all. The overarching aim of the project was to construct a baseline database of surf break physical parameters and processes at 7 of Aotearoa New Zealand’s nationally and regionally significant surf breaks; and to develop sustainable management guidelines which will uphold the integrity of the New Zealand Coastal Policy Statement 2010.

Seven surf breaks were selected for detailed study to encompass the range of different types of surf breaks and the variety of threats to surf breaks within Aotearoa New Zealand. Stakeholder meetings were conducted for each site to collect data and local knowledge relating to cultural, geomorphic and historical background. An important step prior to the stakeholder meetings involved consultation with tangata whenua (local Māori, people of the land) who have kaitiakitanga (guardianship) of each area in order to seek approval for conducting research within their rohe (tribal boundaries), ensure that the research aims and methods aligned with the local Iwi’s values and beliefs and to determine how each surf break is valued and used by Iwi.

Technical data collection was achieved through the use of remote camera stations at each site. The stations collect images of the study sites 7 days a week, 365 days a year. Automated systems process the data and extract important physical parameters. Multiple bathymetric surveys of the seabed at each site were undertaken. The data collected during this project is freely available from an online data portal; with the capacity to add new breaks in the future.



Appendix E. **Consent Conditions and Monitoring**

E.1 Overview

As described in Section 1.2 (Legislative Context) of these Guidelines. surf breaks are relevant to several aspects of the Resource Management Act 1991 (RMA), particularly the purpose and principles of the Act, the purpose of Regional Policy Statements and the purpose of regional plans. The RMA is Aotearoa New Zealand's main piece of legislation that sets out how we should manage our environment (http://www.mfe.govt.nz/rma). The RMA was created to achieve a more coordinated, streamlined, and comprehensive approach to environmental management, and is focused on the sustainable *management* of natural and physical *resources* such as land, air and water; as set out in Section 5 of the Act 'Purposes and Principles'.

The RMA controls specific uses of natural and physical resources through the requirement of resource consent. To gain resource consent for specific activities, an Assessment of Environmental Effects (AEE) is required as part of the application for resource consent. The AEE should include all potential impacts on the environment (see Table 2.4 of these Guidelines for a comprehensive, but not exhaustive, list of potential impacts on surfing resources), assess the level of the potential impacts, and how any adverse impacts can be avoided, remedied or mitigated.

An important component of the resource consent process are the conditions of consent, which are a specific set of procedures and tasks that an applicant must undertake to determine the level of any potentially adverse impacts (usually through environmental monitoring) and/or procedures to be undertaken in order to avoid, remedy or mitigate any adverse impacts on natural and physical *resources (such as surf breaks). A well-written set of conditions that captures the potential and actual impacts and how they should be monitored and the adaptive management procedures that can be applied to* avoid, remedy or mitigate any adverse impacts is fundamental to the successful management of surfing resources.

There are several useful guidelines available for the development of resource consent conditions, such as those provided by Quality Planning[11] (e.g. http://www.qp-test.org.nz/):

"*It is critical that resource consent conditions are drafted carefully to ensure:*

- *they are within the law*

[11] Quality Planning is a collaboration between the New Zealand Planning Institute (NZPI), the Resource Management Law Association (RMLA), Local Government New Zealand (LGNZ), the New Zealand Institute of Surveyors (NZIS), the New Zealand Institute of Architects (NZIA) and the Ministry for the Environment.

- *compliance with the conditions will result in any adverse effects being limited to the extent anticipated by the decision-maker*
- *the consent holder and other parties understand exactly what the requirements are, and*
- *if necessary, enforcement can be undertaken.*

As a consequence, the drafting of resource consent conditions is extremely important."

E.2 Why Consent Conditions?

Conditions of consent come in a variety of forms. With respect to surf resources, they most often address effects that have the potential to change the characteristics of the surf break, although effects on water quality and access to surf breaks are also potential impacts. It is therefore fundamental that baseline data to quantify the characteristics and mechanics of the surf break and surfing waves is collected. In addition, many potential impacts on surf breaks due to various activities on the coast and within the swell corridor are presently unknown due to lack of research. This means that baseline monitoring is critical to determine impacts.

In this section, three examples are presented to show how impacts on a surfing resource can occur, and how their management can be improved by appropriate baseline data collection and suitable conditions of consent.

E.2.1 Aramoana

The impacts of nearshore dredge disposal on the nationally significant surf break of Aramoana at Otago Harbour entrance was controversial when renewals for the dredge disposal resource consents were due in 2013. Aramoana is a high-quality beach break where the offshore ebb-tidal delta focusses waves in to peaks, or 'A-frames' (See Guidelines Glossary), which provide hollow peeling waves (See Appendix A). The surfing fraternity were divided as to whether the nearshore disposal enhanced this focussing effect, enhanced wave quality, or whether the nearshore disposal had led to the beach being over-filled with sediment resulting in a reduction of wave quality (See Appendix A). Similarly, numerical modelling of the combined effects of the offshore delta focussing and nearshore disposal mound focussing were interpreted differently by different experts (some positive and others negative).

Through mediation between the Surfbreak Protection Society (SPS) and Port Otago Ltd, a temporary 3-year permit was granted which greatly restricted the volume of nearshore disposal to determine the impacts of nearshore disposal; it was reduced from 200,000 m^3 to

50,000 m^3. Furthermore, no nearshore disposal was permitted during the first 2 years. Through a combination of remote video monitoring, repeat bathymetric surveys, numerical modelling and surveys of local surfers, it was found that surfing wave quality had markedly improved. This improvement correlated to a reduction in the volume of sand within the Aramoana embayment as it naturally moved westward and around the point. As a result, better management of nearshore disposal at Aramoana is being implemented through restricted disposal volumes. In addition, the location and shape of the disposal mound have been modified to a configuration more conducive to high quality surfing (see example conditions below).

E.2.2 Aquaculture

Wave attenuation through offshore mussel farms has the potential to reduce wave height at the surf breaks. Unlike impacts such as enrichment of the seabed under mussel farms, where degrees of enrichment and the effects of this are well studied, there is very little understanding of the impacts of wave attenuation through mussel farms, which could be positive or negative.

It is known that mussel farms will attenuate short period waves such as local wind-generated waves. The attenuation qualities of kelp beds are positive and well known to surfers; in terms of surfing conditions, this attenuation of short period waves results in 'cleaner', more favourable conditions. However, there is also the potential to reduce wave heights, which in some areas that have only small wave climates and rely on short period waves for surf breaks to operate this attenuation is a negative impact. Therefore, appropriately designed monitoring is required to determine and quantify impacts on surf breaks where offshore aquaculture developments are within their swell corridors (see example conditions below).

E.2.3 Whangamata

The impacts of a marina development on have been very controversial. Whangamata Bar is one of Aotearoa New Zealand's Surf Breaks of National Significance under Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS), was described by the Hawaiian surfing legend Gerry Lopez as the 'gem of the South Pacific', and falls in the most 'sensitive' category of surf break, a delta break.

The marina entrance channel was opened to the sea in 2009. The area of the harbour deepened to develop the marina represents an increase in the tidal prism of the estuary, which in turn has the potential to modify currents at the mouth of the estuary and impact on the ebb tidal delta. The ebb tidal delta is the primary functional seabed component that comprises the

Whangamata Bar surf break. While there is no doubt that detrimental changes to the morphology of "The Bar" occurred during the time that the marina was opened to the sea (i.e. there were negative impacts to the surf break's wave quality in terms of ride length and peel angle), there is insufficient and inadequate monitoring data to confidently determine that it was caused by the marina development, or whether it could have been associated with particular storm events at the time and natural changes in the bar. The reason for the lack of conclusions was because:

a) There was insufficient characterisation of the surfing break prior to the development so changes to wave quality could not be quantified.
b) There was insufficient baseline monitoring to determine natural variation of ebb tidal delta and the area in and around the Surf Break Area (SBA).
c) The monitoring methodology was only directed at one component of the surf break with relatively sparse data capture (i.e. bathymetry surveys every 6 months).
d) The level of investigation was poor as it lacked even a general understating of surf science and surfing resource management

E.2.4 Summary

Comprehensive baseline monitoring is required to quantify surf break mechanics and surfing wave characteristics. Baseline monitoring should be followed by monitoring of any effects to the mechanics and characteristics during and post development or activity (as set out in Sections 2 and 3 of these guidelines). A year of baseline monitoring is considered the minimum, while multi-year baseline data collection will increase confidence in our quantification and understanding of a surf break.

To manage our nationally and regionally significant surf break resources, remote monitoring should be a permanent activity undertaken by the authorities responsible for these sites. Some surf break monitoring methods also have multiple benefits and can assist in a range of areas for regional and local authorities; remote video cameras for example, provide a variety of information about a surf break and its characteristics, and can also be used to consider a range of other parameters such as user numbers (not only of surfers, but other water and beach users), erosion/accretion trends, rips and bars (e.g. safety issues), and extreme events and coastal hazards.

E.3 Baseline monitoring

Baseline monitoring is required in order to determine whether or not an activity(s) impacts on a surf break. Baseline monitoring is focussed on the collection of data that can be used to characterise the surf break (i.e. length of ride, optimum wave height, optimum tidal phase, peel angle, breaking intensity, local seabed morphology, wave height at surf break in comparison to offshore wave conditions, etc.). Baseline monitoring methods include:

- Remote video data collection – this is most cost-effective method of collecting surf-break data, which can be used to determine peel angles, ride length, optimum swell/tide/wind conditions, typical take-off and break location(s), as well as infer seabed morphology and provide further information such as number of users (for all users of the space), beach change, rips and bars.
- Surveys of bathymetry – repeated surveys provide information about changes to the seabed. The use of single or swath bathymetry is dependent on the surf break configuration and the presence of particular features, and the type of activity the conditions of consent are being drafted for.
- Beach profile monitoring– repeat beach profiles, which cover the intertidal and subaerial areas, can use traditional surveying methods or LiDAR, and should overlap with hydrographic survey data.
- GPS tracking of surfers – the geographical position of surfers utilising GPS (the Global Positioning System) (See Appendix A Section 3.3) can be applied to determine ride length, take-off area, sections of the wave, and entry and exit points to the surf break
- Oceanographic data collection – wave statistics (height, period, direction etc.) and in some cases currents at a surf break provide information that can be related to long-term data sets to develop a pre-activity dataset of waves conditions
- Numerical modelling – calibrated numerical models can be used to simulate processes of the existing surf break. Simulations can include various swell events and consider the potential impacts of any changes to the existing environment (e.g. nearshore dredge disposal mounds, harbour channel deepening, offshore sand-mining, etc.).
- Water quality monitoring – activities such as nearshore dredge disposal, dredging, stormwater outfalls, wastewater outfalls, aquaculture, forestry, farming and urbanization can potentially impact on water quality. Water quality standards should follow Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment, 2002; or later editions). Sampling sites must be proximal to surfing areas and target the pollutant.

There is natural variability in the swells that propagate through a swell corridor to a surf break. In some cases, there is natural variability in the bathymetry of the swell corridor and SBA. The requirement to understand this natural variability fosters the need to collect a long, high resolution baseline dataset. The longer a baseline dataset, the more confidence there is in the characteristics and mechanics of the break during a range of conditions.

For example, swells from the northeast may be dominant during summer and autumn months, while southerly swells dominate the winter and spring seasons, which is synonymous to the east coast of the South Island). These different swell directions result in different wave characteristics such as peel angles, wave breaking intensity, wave height and ride length (see Appendix A for detailed definitions of surfing wave characteristics). By monitoring and quantifying this variability, a specific range of parameters can be defined as the baseline characteristics of a break (e.g. wave peel angles are typically between 55 and 65° during northeast swell and 60-70° during southeast swell).

Similarly, beach breaks may have characteristics driven by seasonal wave climate and/or different combinations of wind/wave events. For example, on the north western coast of the North Island, the larger swells of winter and spring often result in shore parallel bars and troughs. This “longshore bar trough” configuration is not often conducive to good surfing conditions. Over the summer months, during which time the wave climate is generally lower energy, the trough often fills in which is associated with better surfing conditions. In addition, and in combination with this seasonal morphodynamics, the variability of the wind/swell conditions can play a large role in surfing wave quality. During periods of prolonged southwest wind and waves (the predominant conditions on the north western coast) shore parallel bars can extend unbroken for long distances along the beach. The result is very few places to surf waves with sufficient quality along the beach. However, when there is a lot of variability in the wind and wave conditions, with periods of winds from the northwest transporting sand back to the south, the number of breaks in the shore-parallel sand bars increases markedly resulting in increased opportunity for good surfing locations. Due to the natural variability and seasonality of the marine environment it is important to collect baseline monitoring data for as long as possible; multi-year datasets provide information on the effects of longer-term oceanographic variation such as El Nino/La Nina.

Sections 2 and 3 of these Guidelines describes the appropriate step within the surf break assessment of the AEE that will lead to the development of specific Conditions of Consent that will *capture the potential and actual impacts, how they should be monitored and the adaptive management procedures that can be applied to* avoid, remedy or mitigate any adverse impacts. These steps are supported by additional information in Section 4 and a comprehensive set of appendices.

E.4 Impact Monitoring and Adaptive Management

Through the resource consent process an AEE should provide the assurance that effects to a surf break (actual and potential) are either less than minor to insignificant, or that any effects can be managed through avoidance, remedying or mitigation before granting resource consent. To determine whether or not the consented activity is having any impact on the potentially effect surf break(s), the monitoring undertaken for baseline data collection is continued and these data are then compared to the baseline data.

It is the conditions of consent that are fundamental to ensuring that:

- **the monitoring design is appropriate to detect and quantify effects.**
- **that methods are established that counter any effects through avoidance, remedying or mitigation.**

Countermeasures are incorporated into conditions through a variety of methodologies that are termed adaptive management. Adaptive management relies on detecting effects through monitoring, quantifying these effects so that if a 'trigger' is met a countermeasure is undertaken, often with further detailed investigations being undertaken.

In many cases, the first response to a trigger being detected is an in-depth analysis of the data that has been collected since the baseline was established, and a more rigorous round of monitoring (e.g. a potentially unscheduled bathymetric survey to confirm the changes observed with other monitoring such as remote video). Triggers for surf break impacts can include, but are not limited to, changes in peel angles, wave breaking location, ride length, crest uniformity, water quality, breaking intensity, wave height and/or direction; and changes in the amount of time that waves are surfable at the break.

If a trigger level is reached measures in the Environmental and Adaptive Management Plan (EAMP) are applied to avoid, remedy or mitigate the impact. For example, a trigger can be set for wave height attenuation due to large scale offshore aquaculture. The effects can be mitigated by counter measures (adaptive management) such as reducing stocking densities within the marine farm; determined by staging the development with incremental increases on stocking densities. Another example of a trigger is a change in sea floor shape, or bathymetry, observable through repeat bathymetric surveys. This is particularly important where previous investigations have indicated that the amount of material in the beach system is important for the quality of the waves at a surf break; this has been applied to the management of Port Otago's nearshore disposal ground at Aramoana. At Whareakeake, wave breaking on the offshore dredge disposal ground breaks the waves and impacts on wave crest uniformity (which is important at point breaks such as Whareakeake), and so a minimum height of disposal mound has been specified in the conditions, with heights above this triggering a reduction in disposal on the crest of the mound (adaptive management). At Taylor's Mistake in Christchurch, there is potential to impact on both water quality and bathymetry at the break due to nearshore maintenance dredge disposal for the Port Lyttleton entrance channel. Monitoring of water quality and with remote cameras is being undertaken to measure these effects.

Should water quality levels be triggered, then adaptive management measures can include disposal during conditions when currents/winds transport the sediment plume offshore. A trigger due to changes in bathymetry due to sediment moving shoreward from the disposal mound will require a re-think with respect to the nearshore disposal site such as relocation (only one site was investigated for the resource consent application); the AEE concluded that this would not occur, while further modelling work as part of mediation between the Port and the Surfbreak Protection Society indicated that sediment would migrate shoreward. The examples presented here are summarised in Table D-1.

Table D-1: Summary table of example activity-trigger-response to be used in adaptive management.

Activity	**Large Scale Offshore Aquaculture**	**Dredge Spoil Disposal**	**Dredge Spoil Disposal**
Trigger	Wave height attenuation	Change to seabed morphology (i.e., depth isobath position)	Wave breaking on disposal ground
Response	Reduce stocking densities	Use of disposal ground temporally halted	Establish threshold for height disposal mound
Potential retrospective avoidance	Incremental increases on stocking densities	Estimate maximum disposal ground capacity in terms of surfing wave quality; combined with pre-disposal surveys	Establish seabed height threshold for wave breaking; combined with pre-disposal surveys

E.5 Example Conditions of Consent

This section presents some examples of appropriate conditions of consent for activities in Aotearoa New Zealand. The first example is concerned with aquaculture proposed for the Firth of Thames, the second looks at the conditions of consent imposed on the Port of Otago for their "Project Next Generation"; lastly, the more recent conditions of contest for the Lyttelton Port Company. The conditions of consent in these examples were developed specifically for type of activity and receiving environment. Conditions of consent will need to be addressed on a case-by-case basis.

E.5.1 Firth of Thames

There is presently very little information and understanding with respect to the extent of wave attenuation as waves propagate through mussel farms, or other aquaculture related structures. Wave attenuation has the potential to impact on wave height at the break, as well as wave-driven currents at the shore which in turn may impact on the sediment transport regime and seabed features that comprise the surf break.

The following conditions were recommended to determine impacts on the surfing resources in the Firth of Thames:

<u>*Wave Monitoring*</u>

- *The monitoring programme for long and short waves shall investigate the impact of the proposed marine farm on waves from the [directions identified from swell corridor investigations] of the farm site. The likely programme shall be undertaken using two wave monitoring devices, being any of the following models of devices: Aquadopp, Vector, Aqua pro, ADCP-waves, or Directional Waverider or a device with comparable or better ways of measuring capability.*
- *Wave monitoring devices shall be installed at two locations; one offshore and one inshore of the proposed farm site prior to any development at the site. The wave monitoring devices shall be installed at the same depth below the sea surface. The devices shall measure and record the direction and height of waves with periods of three seconds and longer. The devices shall collect data for a continuous period of at least two months and include at least two wave events. The data collected shall be analysed to determine if there is any directional difference in attenuation of wave height based on direction across the site.*
- *The monitoring described above shall be undertaken prior to farm development (baseline data), at 50% development and at 100% development.*

- *If the data analysis from the monitoring of the developed farm (either at 50% or 100%) shows that there is a significant directional difference and/or attenuation of wave height based on direction across the site in comparison to baseline data, then the consent holder shall provide a report to the Team Leader Monitoring South outlining the implications of this on coastal processes and surfing amenity on the western Firth of Thames coast, including proposing any remediation that may be required and a programme for continued monitoring.*
- *If the data demonstrates that there is no significant wave dampening effect from the farm structures, the monitoring can cease.*

E.5.2 Port Otago

At Aramoana and Whareakeake, the 3-year temporary dredge disposal consents that allowed Port Otago to gain a much better understanding of the mechanics of these two Surf Breaks of National Significance, a 20-year resource consent was applied for and granted. The new consent includes an extensive increase in the disposal site offshore of Whareakeake (Heyward disposal mound was increased by approximately 5x). This increase permitted better management of the morphology of the disposal mound that effects the surf break. The consent also included conditions regarding the bathymetry at the Whareakeake and Aramoana (specific depths and depth contour locations), and continued remote camera data capture:

Dredging Volumes and Bathymetric Monitoring

7. *(i) The consent holder shall record the following information in relation to the disposal of material at each of the three disposal sites.*

   (a) the volume of dredging material in each disposal event;
   (b) the volume and percentage of each material type in each event;
   (c) the source geographic claim location information;
   (d) the GPS location (WG84 format) of the event;
   (e) the date and time of disposal; and
   (f) a cumulative total of the volumes of disposal (including material type) from the commencement of the consent.

   (ii) The records shall be kept and submitted to the Consent Authority on an annual basis, no later than the anniversary of the date of the commencement of this permit in report format, including digital records that allow for GIS plotting.

8. *As a minimum, the consent holder shall undertake annual bathymetric surveys of the seabed at each of the disposal site locations and the beach areas inshore of the these which have the potential to be affected by the disposal. All bathymetric surveys*

shall have an accuracy of 0.25 metres vertically. The extent and frequency of the bathymetric surveys may be amended with the agreement of the Dredging Working Party and the Consent Authority.

A. *Bathymetric surveys shall be undertaken for the Shelley Beach site that clearly indicates the degree of change to the seabed in the surveyed areas.*
B. *Bathymetric surveys shall be undertaken for the Heyward Point disposal site to check the dimensions and depths of the mound and spur features are within the following limits:*
    (i) *The mound within the cells PB5, 6, 7, PD5, 6, 7 is maintained in its present location and is not less than 9.5 metres below mean sea level;*
    (ii) *The 12 metre depth contour surrounding the mound is greater than 300 metres in diameter;*
    (iii) *That minimal disposal occurs on the spur area within cells PC1, 2, 3, 4 and PD1, 2, 3, 4 illustrated on Figure 1 as attached as Appendix 1 to this consent; and*
    (iv) *That the balance of material is spread out evenly.*

Advice Note – The limits have been specified to ensure that the mound is managed in a manner that avoids it becoming too high above the natural seabed level, or the sides of the mound becoming too steep. This is required to avoid the creation of wave interference patterns and wave crest disruption at the Whareakeake surf break.

C. *Bathymetric surveys shall be undertaken for the Aramoana disposal site to check the positions of the 5, 6, and 7 metre depth contours are consistent with the historical positions illustrated on Figure 2, Figure 3 and Figure 4 as attached as Appendix 1 to this consent.*

    Where there is departure from the specified contour levels at the Heyward Point or Aramoana disposal sites, a review of the bathymetric surveys shall be undertaken by a suitably qualified expert in coastal processes to identify the potential for adverse effects on wave and sediment transport, and the adaptive management process outlined in Condition 18 shall be commenced.

9. *A visual or photographic record of surf conditions shall be maintained and archived for the Aramoana and Whareakeake surf breaks. This shall be made available and reviewed as necessary by the Dredging Working Party, in the event that the adaptive*

management Condition 18[12] is triggered and the Dredging Working Party identifies a potential surf quality issue. These data are to be recorded through webcams or alternative technology as agreed with the Dredging Working Party. Visual recording may be discontinued in the future, with the agreement of the Working Party and the Consent Authority.

10. *Beach profile surveys for the Aramoana, Kaikai, Whareakeake, Long Beach, Pūrānkaunui, Warrington Spit, Karitane and Shelley Beach shall be undertaken annually by a suitably qualified expert in coastal processes for the first five years from the date of the commencement of this permit and thereafter once every five years for the term of this consent. A beach monitoring report shall be provided to the consent authority following each profile survey with an assessment of the rate and extent of sediment accumulation at the beaches in Blueskin Bay and the effect of disposal activities on erosion or accretion of the beach. Where this report identifies any adverse effects potentially attributable to disposal activities, the adaptive management process outlined in Condition 18 shall be commenced.*

E.5.3 Lyttleton Port Company

In Canterbury there is the potential for nearshore maintenance dredge disposal by Port Lyttleton Company to impact on both water quality and bathymetry at Taylor's Mistake and possibly other surf breaks. Following an appeal by the Surfbreak Protection Society, the following conditions were included in the resource consent for maintenance dredge disposal:

14. SURFING LIAISON GROUP (SLG)

14.1 *Not less than three months prior to the first Dredging Campaign, the consent holder shall establish the SLG by inviting representatives from the surfing community described in condition 14.3 (a) and (b) to participate in a SLG.*

14.2 *The purposes of the SLG are:*

(a) *To enable the consent holder and the surfing community to share information relating to surf wave quality and the exercise of this consent; and*

---

12 Convene Dredging Working Party

(b) *To discuss the monitoring required by this consent, insofar as it relates to the effects of exercising this consent on the Surfbreaks.*

14.3 *Invitations to participate in the SLG shall be extended to:*

(a) *The Surfbreak Protection Society who shall be entitled to appoint up to* 2 *representatives to the SLG; and*

(b) *Local surfers who shall be entitled to appoint up to* 2 representatives to the SLG.

14.4 *The consent holder shall be entitled to appoint up to 3 representatives to the SLG.*

14.5 *Once established, the consent holder shall offer to hold meetings of the SLG prior to the commencement of each Dredging Campaign under this consent.*

14.6 *The consent holder shall provide no less than two weeks' notice of all SLG meetings, provide a venue and agenda for the meetings, and shall keep minutes of those meetings and distribute them within five working days but otherwise the costs of participation in the SLG shall lie where they fall.*

15 BATHYMETRIC MONITORING AND ASSESSMENT

15.1 *The consent holder shall five years after the first Dredging Campaign review the results of the bathymetric monitoring required under condition 7.19 and evaluate whether Dredge Spoil deposition and associated mound height at the offshore maintenance disposal ground is consistent with the modelling outputs contained in the Met Ocean Solutions Ltd Report (dated November 2017).*

15.2 *Where the evaluation carried out under condition 15.1 determines that the mound heights are inconsistent with the modelling outputs contained in the Met Ocean Solutions Ltd*

Report (dated November 2017), the consent holder shall engage a suitably qualified and experienced expert to:

(a) *Review the bathymetric data;*
(b) *Rerun the model;*
(c) *Evaluate and provide reasons for the discrepancy between the bathymetric data and the modelling outputs; and*
(d) *Evaluate any changes to the predicted effects on Surfbreaks.*

15.3 *The consent holder shall provide a report to the SLG and the Consent Authority on the results of the review of the bathymetric monitoring*
completed under condition 15.1, and, if required, any review and evaluation completed under condition 15.2.

15.4 *The consent holder on request from the representatives of the Surfbreak Protection Society or the local surfers on the SLG shall convene a meeting to discuss the contents of the report* prepared under condition 15.3, and consider whether any management actions or whether any additional monitoring is needed.

15.5 *Recommendations made by the SLG and adopted by the consent holder shall be incorporated into the report prepared under condition 15.3 and the revised report shall be provided to the SLG and the Consent Authority. Any recommendations that are not adopted are to be included in the report together with the reasons why they were not adopted.*

15.6 *The report prepared under condition 15.3 shall be completed no later* condition 15.1 and any revised report shall be completed within two months of any meeting held under condition 15.4

7 MONITORING

7.27 *Prior to the commencement of the first dredging campaign the Consent Holder shall install a system to capture and archive a video or photographic record of the surf conditions at Taylors Mistake surf break and shall maintain the system for the duration of this consent. The visual or photographic record shall be recorded via a remote web-based camera system with suitable resolution and field of view to enable extraction of georeferenced* *images for all of Taylors Mistake Surf Break. The data and images shall be made available to the SLG, solely for the purposes of informing the processes and outcomes of conditions 15.2, 15.3 and15.4.*

Appendix B. Development of the Regional Significance Concept for Surf Break Management in Aotearoa New Zealand.

Publication details:

Orchard, S; Atkin, E.A., and Mead, S.T., 2019. Development of the Regional Significance Concept for Surf Break Management in Aotearoa New Zealand. In: Bryan, K.R. and Atkin, E.A. (Eds.), Surf Break Management in Aotearoa New Zealand. Journal Of Coastal Research, Special Issue No. 87, Pp. 23-34. Coconut Creek (Florida), ISSN 0749-0208.

 Pagination of the reproduced article is carried over from publication and not synchronised with the main body of this thesis.

Journal of Coastal Research	SI	87	23–34	Coconut Creek, Florida	2019

Development of the Regional Significance Concept for Surf Break Management in Aotearoa New Zealand

Shane Orchard[†§*], Edward A. Atkin[††‡], and Shaw T. Mead[††]

[†]Waterlink Ltd
Christchurch, New Zealand

[§]University of Canterbury
Christchurch, New Zealand

[††]eCoast Marine Consulting and Research
Raglan, New Zealand

[‡]University of Waikato
Hamilton, New Zealand

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Orchard, S; Atkin, E.A., and Mead, S.T., 2019. Development of the regional significance concept for surf break management in Aotearoa New Zealand. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand*. *Journal of Coastal Research*, Special Issue No. 87, pp. 23-34. Coconut Creek (Florida), ISSN 0749-0208.

New Zealand is at the forefront of global developments in the management of surf breaks. Since establishing legal protection under the New Zealand Coastal Policy Statement 2010 the focus has shifted to the implementation responsibilities of local government. Within this context, a new planning mechanism has evolved around the concept of identifying surf breaks of 'regional significance' as a focus for protective measures. This paper provides a comprehensive review of these new developments including the different approaches taken in technical assessments and statutory plans to date. Although the concept is still in its infancy, there have been a range of approaches used that differ in many important aspects. These include the information sources relied upon, methodologies for community participation, and the rationale for conferring regional significance status. Two major paradigms can be identified in the design of assessment processes: the direct nomination of surf breaks for regional significance by local knowledge holders, and the assessment of surf breaks against regional significance criteria and associated qualifying thresholds. At the current point in time there are a range of philosophical decisions to be worked through in relation to the intended role in the management context, and the non-disclosure of sensitive locations leading to their exclusion from assessments. The current examples provide an important starting point towards a comprehensive approach for recognising national, regional and local levels of significance. Further developments can be expected as management authorities incorporate and build upon on these new approaches to surf resource management.

ADDITIONAL INDEX WORDS: *Surfing, coastal environment, resource management, assessment criteria, regional significance.*

INTRODUCTION

Surf breaks are natural features of the coastal environment that have a long history of association with communities and cultures (Kelly, 1973; Skellern *et al.*, 2013). However, coastal development has often come at the expense of these resources, leading to the need for improved protection (Nelsen, Cummins and Tagholm, 2013). Global responses have included grassroots activism and campaigns aimed at drawing attention to the plight of surf breaks, complemented by steady progress towards more formal approaches to surf break management. The latter includes the development of surfing reserves at national and international scales (Farmer and Short, 2007; Short and Farmer, 2012), and the legal protection of surf breaks in New Zealand (Department of Conservation, 2010; Orchard, 2011), and Peru (Monteferri, 2013).

In comparison to the many examples of reactive, issue-driven advocacy work, the prior recognition of values is a key consideration for the design of proactive protection and management mechanisms. This generates the need for assessments to identify surf breaks so that they can be included in resource management frameworks. The design of such assessments is fundamental to the protection outcomes that might eventuate and includes aspects such as the rationale for identification or inclusion of surf breaks within a planning initiative, and the processes by which information is gathered and decisions are made.

Internationally, there is no standard approach or set of assessment criteria for conducting such assessments. To date, both top-down and bottom-up approaches have been used for nomination and decision-making, and there is potential to combine the beneficial aspects of each (Orchard, 2017a). Merits of bottom-up approaches, as exemplified by Australia's National Surfing Reserves programme, include the requirement for strong community buy-in for a proposed protection status that is typically backed by considerable evidence of the importance and values of the surf break (Orchard, 2017b). This method also underpins the framework for attaining "World Surfing Reserve" status attributed by the international surf break protection advocates Save The Waves (Short and Farmer, 2012).

DOI: 10.2112/SI87-003.1 received 28 August 2019; accepted in revision 6 September 2019.
*Corresponding author: s.orchard@waterlink.nz

In contrast, New Zealand's 17 Surf Breaks of National Significance (SBNS) were established as part of the New Zealand Coastal Policy Statement (NZCPS) (Policy 16; Department of Conservation, 2010) using a top-down approach to identify a list of qualifying breaks within the context of a statutory policy review. The basis for the selection of the 17 Surf Breaks of National Significance was somewhat subjective. The Wavetrack New Zealand Surfing Guide (Morse and Brunskill, 2004) was used, with breaks rated 10 out of 10 on the author's "stoke rating" being selected as nationally significant; Papatowai and 'The Spit' at Aramoana were also included.

In comparison to the National Surfing Reserve programme, the evidence base for qualification was not as comprehensive. This method did, however, result in the rapid identification of a set of surf breaks for immediate protection (Orchard, 2017b). The approach used in Peru includes elements of both Australasian systems. In that case, a national-scale legal protection mechanism was created (Congreso de la Republica Perú, 2013), that relied on a subsequent assessment process to identify the surf breaks to which it would apply (Monteferri, 2013).

New Zealand provides an example where the context for assessing surf breaks for protection has been made very specific because the term 'surf break' has been defined directly in the NZCPS and subsequently used in the construction of national policies that have legal effect (Figure 1).

A natural feature that is comprised of swell, currents, water levels, seabed morphology, and wind. The hydrodynamic character of the ocean (swell, currents and water levels) combines with seabed morphology and winds to give rise to a 'surfable wave'. A surf break includes the 'swell corridor' through which the swell travels, and the morphology of the seabed of that wave corridor, through to the point where waves created by the swell dissipate and become non-surfable. 'Swell corridor' means the region offshore of a surf break where ocean swell travels and transforms to a 'surfable wave'. 'Surfable wave' means a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the wave crest.

Figure 1. Definition of the term 'surf break' under the New Zealand Coastal Policy Statement 2010 (Department of Conservation, 2010).

The implication of this definition is that a large number of locations either currently, or in the future, could meet the definition of a surf break. This arises through a combination of contributing factors that include the presence of long stretches of wave-exposed coastline, and the applicability of the term 'surfable wave' to all forms of wave riding pursuits (Peryman and Orchard, 2013). Indeed, it can be argued that legal protection already applies to a large number of surf breaks under national policy as set out in the NZCPS (Skellern *et al.*, 2013). This gives rise, firstly, to the need to assess and identify those surf breaks that do qualify for the protection that the NZCPS confers, and secondly to develop effective methods for achieving that protection to at least the degree required under the relevant policies.

While NZCPS defines a surf break, it provides no direction with respect to defining the significance of a surf break. Whereas SBNS were identified directly within the NZCPS, one of the important developments has been the application of the significance concept at the sub-national scale (Figure 2) to identify Surf Breaks of Regional Significance (SBRS). These developments have occurred progressively in different regions of New Zealand within the context of the review cycles of statutory policies and plans (Orchard, 2017b).

To date, there have been a variety of methodologies used that differ in aspects such as qualifying criteria, the knowledge base relied upon, and the degree of community participation. The objectives for this paper are to (i) review the history of these developments, (ii) compare the methodologies used in relation to the geographic context of each region and the needs of managing authorities, and (iii) discuss implications of the different approaches in relation to the design of policy and planning methods for achieving sustainable surfing resource management.

RESEARCH APPROACH

A case study of New Zealand's current experience in applying the regional significance concept to surf break management is presented. Following a case-based analytical approach (Yin, 2003), a review was undertaken of all the available information on the topic with a particular focus on examples of where statutory recognition has been conferred to SBRS in response to the NZCPS 2010. The sources of information included peer-reviewed literature, technical reports, grey literature, legislation, policies, policy statements, and statutory plans.

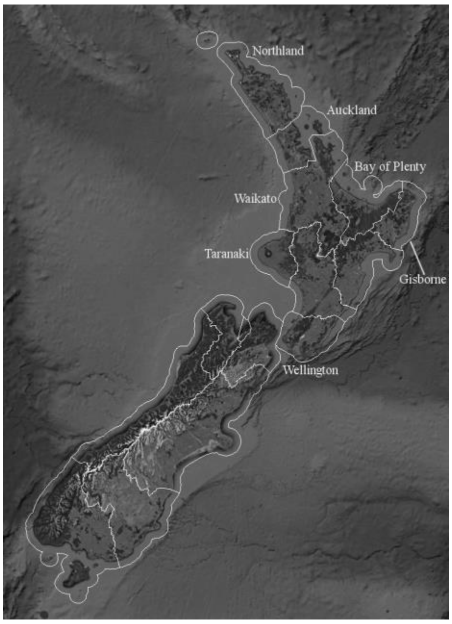


Figure 2. The 2018 regional level boundaries in New Zealand overlaid on a Google Earth image, with annotation for the regions relevant to this research.

The methods included a literature search for relevant documentation followed by content analysis to support a comparative evaluation of methodologies. A policy analysis of statutory policies and plans was used to characterise the resource management context within which these developments occurred.

STATUTORY PROTECTION EXAMPLES

New Zealand has produced six examples where the SBRS concept has been applied within a regional policy or plan (Table 1). The earliest example (TRC, 2010) pre-dated the release of the NZCPS 2010 but was influenced by the proposed NZCPS that served, inter alia, to put surf break protection firmly on the resource management agenda (Department of Conservation, 2008).

In each case, the regional policy and plan development processes that contributed to the management initiatives were supported by technical studies that were undertaken to characterise the surfing resource, identify criteria or methodologies for regional significance assessment, or make direct recommendations on the surf breaks that might qualify. Technical studies have also been completed in two regions for which statutory provisions have, to date, not been made for SBRS (Atkin and Mead, 2017; Peryman, 2011b). The approaches used in those studies are included in the evaluation of methodologies for regional significance assessment.

METHODS FOR ASSESSING REGIONAL SIGNIFICANCE

Assessment Approaches

Two contrasting themes are evident in the application of the SBRS concept to date. In four of the six examples, the approach has been to accept all surf breaks that are identified in a popular guidebook (Morse and Brunskill, 2004) as a starting point on the basis that they are well enough known to qualify for regional significance status, and accept other surf breaks nominated by stakeholders who have been identified as local knowledge holders (Table 1). For example, in a study in the Waikato region, Atkin and Mead (2017) applied the Wavetrack (Morse and Brunskill, 2004), other surf break and beach guides (Bhana, 1996; Rainger, 2011), surf-based website information and a local consultation and knowledge approach to identify surf breaks for consideration in a coastal plan review. A different approach was applied in the two most recent statutory planning examples (Table 1). The distinctive feature of these was the application of assessment criteria to separate surf breaks of regional significance from other known surf breaks in the region. The criteria used are described in the following sections.

Regional Significance Criteria

Criteria for the assessment of surf break values were proposed by Coombes and Scarfe (2010) in the context of making policy recommendations for the Auckland Regional Policy Statement (RPS). They were applied to characterise a list of regional surf breaks identified from Morse and Brunskill (2004), information from the Surfbreak Protection Society (a New Zealand based not-for-profit organisation), and the local knowledge of council staff. The values criteria were not used to separate surf breaks into categories such as regionally or locally significant. Instead, the focus was to provide information on important aspects of the surf breaks for management (Coombes and Scarfe, 2010; McNeil and Coombes, 2012). Subsequently, the draft list of SBRS was subjected to further consultation with the community, and this resulted in several amendments prior to being adopted within the Auckland Unitary Plan which incorporated the RPS (AC, 2016).

Table 1. *Regional policy statements and statutory plans in New Zealand that have identified surf breaks of regional significance, and the methodologies used for identification.*

Date	Policy instrument	Methodology	References
2010	Regional Policy Statement for Taranaki 2010	Surf breaks identified in Wavetrack* and others nominated for inclusion through consultation with local surf community	TRC (2004; 2010)
2015	Proposed Natural Resources Plan for the Wellington Region, July 2015	Surf breaks identified in Wavetrack* and others nominated for inclusion through consultation with local surf community	GWRC (2015) Gunson et al. (2014) Atkin et al. (2015)
2016	Auckland Unitary Plan Operative in Part, December 2016	Surf breaks identified in Wavetrack*, local knowledge of local council staff, and consultation with local community	AC (2016) Coombes and Scarfe (2010) McNeil and Coombes (2012)
2016	Proposed Bay of Plenty Regional Coastal Environment Plan, November 2017	Surf breaks identified in Wavetrack* and others nominated for inclusion through consultation with local surf community	BPRC (2017) Peryman (2011a)
2017	Proposed Regional Plan for Northland, September 2017	Surf breaks identified in Wavetrack* or nominated by local expert panel + assessment of overall importance by local expert panel + application of a cut-off score used to define regional significance status	NRC (2016b; 2017)
2018	Proposed Coastal Plan for Taranaki, February 2018	Regional inventory of surf breaks + community survey of surf break values + assessment of surf breaks against regional significance thresholds for individual criteria	TRC (2017; 2018) Orchard (2017c)

**Wavetrack refers to Morse and Brunskill (2004).*

Although the assessment criteria proposed by Coombes and Scarfe (2010) were not used directly to identify significance, they remained influential and were the subject of further research in the following years. In 2011, SBRS were considered in the context of planning studies in the Bay of Plenty and Gisborne Districts (Peryman, 2011a,b). In the Gisborne study, surveys were used to gather information from community members on the importance of 20 factors relevant to surf breaks. The factors considered were derived from Coombes and Scarfe (2010), and additional considerations identified by the researcher (Peryman, 2011b). The Bay of Plenty study utilised a reduced set of 11 assessment criteria following a similar approach (Peryman, 2011a). The combined data from both studies were evaluated by Peryman and Orchard (2013) to identify the major categories of value associated with surf breaks from the perspective of the coastal communities in those regions (Table 2). For each of these value categories there are a variety of contributing aspects, many of which are underpinned by the unique physical attributes, or geographical setting.

In these studies, the surf breaks selected had already been nominated for regional significance by local knowledge holders rather than having been identified through an assessment process itself. The focus was on understanding the values associated with regional surf breaks from the wider community perspective (Figure 3). In this respect the rationale was similar to that of Coombes and Scarfe (2010; also see McNeil and Coombes, 2012) but extended beyond an expert panel assessment to incorporate a wider community perspective. The values identified provided useful evidence to support the selection of criteria for more comprehensive regional assessments.

Northland provided the first example of specifically designed regional significance criteria being used to identify surf breaks that were subsequently adopted in a statutory plan. Initially, 17 attributes were considered to be potentially useful for the assessment, based on a review of the previously mentioned literature. Seven attributes were considered to be ‘primary attributes’ of greater importance (Table 3). These were used to rate surf breaks in the region using a 10-point scale (NRC, 2016a, b). The concept of regional significance was then derived from a weighted sum Multi Criteria Analysis (MCA). Scores for wilderness and rarity attributes were down-weighted to half weight. This resulted in a summed score out of 60 for each surf break, to which a threshold score of 31 or more was applied as a means to qualify SBRS status (NRC, 2016b).

Table 2. *Categories of value identified from community surveys in the Bay of Plenty and Gisborne regions. Adapted from Peryman and Orchard (2013).*

Theme	Value categories	Contributing aspects
Social	Physical and mental health benefits	- Surf breaks are host to many user groups who participate in many different forms of recreation with positive qualities for physical and mental health for people of all ages and walks of life
	Educational value	- Surf breaks are venues for skills learning, including encouragement of young / learner surfers to participate, hold contests, and socialise in a supportive environment
	Enabling social interactions	- Surf breaks support a diverse range of interactions that contribute to a social fabric that extends into wider communities
	Lifestyle value	- Surf breaks contribute to healthy, family-orientated and community-based lifestyles
	Spiritual value	- Surf breaks are a source of spiritual energy and a place to exercise spirituality important to individual health and community well-being
	Experiential and amenity values	- Surf breaks contribute to scenic and naturalness values important to recreational users, onlookers, coastal inhabitants and visitors - Surf breaks contribute to visual and oral expressions of place – interconnected to wider landscape and seascape values - Surf breaks contribute to the nature and memorability of experiences in the coastal environment - Raw and undeveloped natural landscapes and seascapes contribute to the opportunities for wilderness experiences - Built access and facilities can contribute to surf break amenity though are not always desirable
Cultural	Cultural use and enjoyment	- Access to, use and enjoyment of surf breaks are important aspects of the link between coastal culture and surf break environments
	Places of cultural significance	- Many surf breaks are associated with important cultural or heritage associations and some are considered ‘sacred treasures’
Economic	Commercial activities and economic effects associated with surf breaks	- Surf-related tourism and surfing industry activities are important to local, regional and national economies - Surfing is extensively used in the marketing and promotional activities and contributes to the branding of many commercial products as well as visitor and lifestyle destination - The contribution of surfing to healthy lifestyles has physical and mental health benefits that contribute to economic considerations
Environmental	Natural features and life-supporting systems	- A range of physical aspects of the both terrestrial and aquatic environment contribute to the existence, character, and uniqueness of surf breaks - The ecology and ecological health of surf breaks, adjacent areas, and upstream catchments can influence use and enjoyment - Surf breaks have environmental educational value as sites for experiencing aspects of the coastal environment

Figure 3. Examples of surf breaks in New Zealand that support important values for different sectors of the community: big wave locations like Papatowai in the deep south of Otago (top left; image: Mark Stevenson); 'nursery' breaks suitable for learning wave riding skills such as Lyall Bay, Wellington (top right; image: Linden School); isolated locations that offer wilderness experiences and the opportunity to find uncrowded waves, this shot was taken at a remote, undisclosed location in Fiordland during Red Bull's *Chasing the Shot* campaign (bottom left; image: Matt Dunbar); and, high amenity locations that are valued because of their convenience, accessibility, or presence of facilities like Main Beach at Mount Maunganui where the backshore environment is heavily urbanised (bottom right; image: Jamie Troughton).

Orchard (2017c) proposed a different approach for the assessment of surf breaks in Taranaki (Table 3). The rationale was based on an analysis of the management context which identified the need for the statutory protection of a diversity of surf break types. It recognised that the wide variety of community values that are associated with surf breaks are often underpinned by specific attributes that are unique to a given location. Consequently, surf breaks of value to the community may not always be reliably described by a suite of attributes acting in combination, as was the focus in the Northland. To address this, an alternative methodology was developed whereby attributes of value were first identified and presented in a typology, and each primary attribute was scored individually against a threshold for regional significance which was set at the mid-point of a Likert scale (Orchard, 2017c). In this manner, the concept of regional significance is directly related to evidence of value to the community. It is also inclusive of multiple perspectives on value whilst avoiding the need for subjective weighting. The typology contained many of the primary attributes identified by Coombes and Scarfe (2010; also see McNeil and Coombes, 2012) and NRC (2016b) with refinements to reduce overlaps between attribute definitions while ensuring coverage of all major value categories. Secondary attributes were identified to illustrate important dimensions of each primary attribute as an aid for definition and consideration in assessments. Table 3 summarises the criteria used for the regional significance assessments in Northland (NRC, 2016a,b) and Taranaki (Orchard, 2017c).

Information Sources and Community Participation

The information base relied upon is an important aspect theme for all significance assessment methodologies. Although there is a wealth of popular literature and online guides to surfing locations (*e.g.*, Bhana, 1996; Morse and Brunskill, 2004; Rainger, 2011), these sources typically cover the well-known surf breaks and contain only a subset of the information on surf break attributes that may be useful for an assessment of regional significance. To fill this gap, local knowledge is a particularly valuable information source for characterising surf resources and identifying stakeholders. Opportunities for community participation are also important in assessment processes, especially where existing information is sparse.

Table 3. Attribute typology for the assessment of regional significance based on Orchard (2017c) showing the relationship to attributes used in Northland (NRC, 2016b). Secondary attributes are key components of primary attributes for which examples only are shown, others may be identified.

Primary attributes	**Description**	**Secondary attributes*from Orchard (2017c)**
Rarity of surf break types	How representative is the surf break in terms of its type in the region	surf break types as defined by suitability for different activities, *e.g.*, beginner surfers, big wave surfing etc. oceanographic & morphological characteristics (*e.g.*, point break, beach break; see Mead and Black, 2001)
Wave quality	Quality of the waves for the wave riding activities practiced there, as assessed under near optimum conditions.	length of ride; wave shape; wave power; wave height range
Consistency	Frequency of surfable conditions	surfable days/year or season; consistency of quality
Uniqueness	Recognises the importance of the location to the regional surf break resource in conditions when other breaks are not favourable	relationships with other surf breaks in different weather and swell conditions
Naturalness	Recognises the degree to which the surf break is free from modifications to the natural environment *e.g.*, in relation to the presence of particular flora and fauna, and absence of man-made structures and pollutants. This attribute was combined with Wilderness by NRC (2016b)	proximity and design of structures or other modifications to the natural environment; occurrence of particular ecosystems, vegetation types, or wildlife; condition and legibility of landforms and/or formative coastal processes; water quality parameters / pollutants *e.g.*, plastics; sounds and smells
Wilderness value	The level of remoteness / isolation or exposure to the elements the location offers. This attribute was combined with Naturalness by NRC (2016b)	level of exposure to the elements, difficulty of human access or commitment required to reach the location; low number of users
Amenity value (Taranaki only)	Recognises the importance of aspects that contribute to the pleasantness of the location including aesthetic aspects, the perception of beauty or memorability of the location, and others such as the ease of access and the presence of facilities	presence of services and facilities; proximity to home; scenic qualities and other aesthetics; memorability
Level of use	Recognises the popularity of the surf break in terms of the frequency of use and number of people who derive value from it	frequency of use; diversity of uses or associations with the surf break; numbers of people involved
Economic value to the community (Taranaki only)	Recognises the level of economic importance of the surf break for local communities and/or the wider regional community	promotional value for visitors to the local area or region, including as a component of international appeal; economic activity associated with visitation modes; contributions associated with events or contest venues
Historic, heritage, and cultural associations (Taranaki only)	Recognises the contribution of the surf break to historical and heritage values	long standing boardriding or surf lifesaving clubs; historical events; importance to contemporary coastal culture; contribution to the local sense of place; tangata whenua[†] values associated with the surf break
Education (Northland only)	Focus for skills learning, including encouragement of younger/learner surfers to participate and socialise. This attribute was an aspect of Rarity in Orchard (2017c)	recognition of surf break types as defined by suitability for different activities including learning

**Important components – others can be identified*
[†]tangata whenua may be translated as the 'people of the land' and refers to the indigenous people of New Zealand

Methodologies for gathering local knowledge have included workshops, interviews, surveys (both in person and online), and a range of stakeholder engagement methods including publicly advertised participation opportunities and snow-ball sampling strategies whereby identified stakeholders are invited to identify other knowledge holders - who are then extended an invitation to participate (Salganik and Heckathorn, 2004).

Local knowledge has also been incorporated directly in the identification of surf breaks of regional significance. For example, even the simplest of approaches that take the form of 'creating a list' have provided opportunities for knowledge holders to apply their judgement in determining which surf breaks to include. However, in the examples to date, different approaches have been used to identify and coordinate the group of knowledge holders who make that judgement. They include public meetings, targeted consulting with stakeholder groups, interviews with key informants, appointment of expert panels, and surveys of community knowledge (Table 4). Participatory methods have also been applied to the rating of surf breaks against regional significance criteria in several studies to date. The first example was Coombes and Scarfe (2010) through the use of a four person panel. The following year similar assessments were completed in the Bay of Plenty and Gisborne, by eight participants in each case, who were recruited at public workshops and stakeholder meetings (Peryman, 2011a,b). In these studies the rating results were recorded to help characterise known surf breaks, but they were not used directly to identify regional significance. In Northland, an expert panel consisting of seven stakeholder group representatives was used to evaluate known surf breaks and assign regional significance status (NRC, 2016a). Criteria for the selection of panel members included a minimum of 10 years experience surfing in the region at a variety of surf breaks, having an advanced level of surfing skill, and having a strong standing within the local surfing community. Key tasks assigned to the panel included identifying surf breaks for assessment, selecting assessment criteria, identifying indicators and thresholds for rating the surf breaks against the criteria, weighting the scores based on their perceptions of significance, and determining a threshold score to define regional significance status based on the results (NRC, 2016b).

The recent Taranaki example also used a participatory approach to rate surf breaks against regional significance criteria for inclusion in the regional plan. The participatory opportunity was made accessible to the wider coastal community through the use on an online survey. This approach attracted 338 participants who generated a large body of information on Taranaki surf breaks (TRC, 2017). Steps included: (i) compiling an inventory of surf breaks for assessment, (ii) identifying the regional significance criteria, scoring system and significance thresholds, (iii) developing an online survey platform, (iv) promotion of the survey to the community, and (v) analysis against significance thresholds (Orchard 2017c, 2018).

Significance Threshold

The setting of a significance threshold has been of central interest in the two most recent examples due to its direct influence on the identification of non-qualifying surf breaks in relation to the total number assessed. The topic was originally addressed by Coombes and Scarfe (2010) who considered that the assessment of values was important to provide information on why each break is important, but their use to distinguish surf breaks into categories might be arbitrary and / or simply unnecessary.

In the Northland example, 26 of the 70 identified surf breaks assessed were found to be non-qualifying on the basis of the weighted sum MCA result with a significance threshold set at 31 out of a maximum score of 60. In this example it is important to bear in mind the effect of the weighting decision on the final scores and the summed scoring scale, as well as the choice of significance threshold.

In the recent Taranaki example, the community survey results have been made publicly available and are being analysed as part of the plan review process. The initial assessment of council staff (TRC, 2017) against the regional significance criteria (Orchard, 2017c) is currently under consultation with key stakeholders who will provide their feedback in an upcoming hearing. In this analysis, important considerations include the information sufficiency requirement, which relates to the minimum number of knowledge holders thought be required for a robust assessment, as well as the threshold to be applied to assessment scores (Orchard, 2017c). Different combinations of these factors have a considerable effect on the number of surf breaks that qualify for regional significance. For example, using the numerical threshold of >3 on a five-point scale as recommended in (Orchard, 2017c), the information gathered shows that 125 surf breaks qualify with the minimum number of survey responses set to two, but only 109 surf breaks if the minimum number is set to five (Orchard, 2018).

Table 4. Participatory methods used in assessments of regional significance in New Zealand.

Methods	Region	References
Consultation with key stakeholder groups (*e.g.*, boardriders clubs)	Taranaki Auckland	TRC (2010) TRC (2017) Coombes and Scarfe (2010) McNeil and Coombes (2012)
Public workshops	Gisborne	Peryman (2011b)
One-on-one interviews with local knowledge holders	Bay of Plenty Gisborne Waikato Wellington	Peryman (2011a,b) Gunson, Orchard and Windsor (2014) Atkin and Mead (2017) Atkin, Gunson and Mead (2015)
Appointment of an expert panel	Northland	NRC (2016a,b)
Surveys of community knowledge	Bay of Plenty Gisborne Taranaki	Peryman (2011a,b) TRC (2017) Orchard (2017c)

DISCUSSION

Role of Regional Significance Status

To date the New Zealand context for surf break management has been heavily influenced by top-down policy initiatives under the NZCPS. In addition to provisions for Surf Breaks of National Significance (SBNS), a mandate for protection has been established that applies to all surf breaks in relation to the protection of natural features and natural landscapes, and the preservation of natural character (Orchard, 2019). Authorities are obligated to give effect to the NZCPS by incorporating surf breaks into policy and planning using methods such as characterisation of the resource and formulation of appropriate objectives, policies and rules. The concept of regional significance has been explored by several local authorities as a means to give effect to these responsibilities.

Although the NZCPS identifies the surf breaks of national significance directly through use of a schedule, it does not provide guidance on the further stratification of surf breaks according to significance concepts (*e.g.*, regional or local significance categories). Rather, these concepts have evolved in the context of regional policy development and planning. The extent of effort that has gone in to these exercises is in response to pressure from environmental groups and the cases of resource degradation/preservation that they have become involved with.

In all cases, regional significance has been used to confer status to a set of surf breaks within the region, to which specific planning methods are then applied for the purpose of achieving a degree of protection. This illustrates that the role of regional significance status as a management tool is closely linked to the proposed level of protection. In New Zealand, the latter has proven to be variable depending on different interpretations of the NZCPS, and the level of commitment to surf break protection by the management authorities with responsibilities for its implementation (Orchard, 2017b).

Development of Methodology

Two distinct paradigms in the identification of regional significance as a tool for surf break management have been identified. These are described below followed by a discussion of management implications.

Paradigm 1: Direct nomination of surf breaks for regional significance by local knowledge holders

This concept was exemplified by the first four regions to identify surf breaks of regional significance, although using different methods to elicit the community input in each case. An aspect in common for these approaches is that the threshold for significance rests largely with the perceptions of those participating in the assessment. It is important to note the marked difference from the concept of identifying all of the surf breaks in a region, as defined by the NZCPS (Figure 1). This relates to the distinction between locations known to be surfed, versus those that are 'surfable'. The latter is the operative term in the NZCPS definition of surf break, and number of such locations can be expected to be considerably greater than the surf breaks that are known to be used at any particular point in time. The assessment currency is therefore an important consideration in light of new developments in wave riding equipment, and the strong growth of new recreational disciplines such kite-boarding and stand-up paddle boarding. These activities occur at locations that meet the definition of surf breaks and yet may not have been used extensively for other forms of wave riding in the past. This illustrates that the usage of surf breaks for various wave riding activities can be expected to change over time. Given an increase in the diversity of wave riding equipment, and an increasing coastal population worldwide (Small and Nicholls, 2003), there is likely to be an increasing trend in the number of surf breaks used for recreational pursuits.

Paradigm 2: Assessment of surf breaks against regional significance criteria and an associated qualifying threshold

The distinguishing feature of this approach is the application of explicit significance criteria to define and identify a set of qualifying surf breaks. In comparison to the abovementioned approach, there is a higher requirement for information to be documented and the final evaluation is evidence-based. Experience with the two examples to date has shown that subjectivity remains in the nuances of setting the significance threshold. This is ideally dealt with in the design of the methodology at the outset to avoid the need for arbitrary threshold decisions after the assessment has been completed.

Different MCA models have been applied in the two assessments to date, and inherent in these are different implications for the definition of regional significance. Using a summed score approach implies that the significance concept is equated with a suite of values. The weighting of the component scores introduces a further layer of complexity that needs to be solved by the assessment team. The setting of the significance threshold has a strong philosophical element in deciding where to place the cut off point. With only the single summed score being considered, the interpretation is clearly oriented towards identifying the 'best of the best' or some other subset of the resource in relation to the maximum possible score.

In the alternative approach used in Taranaki, the significance threshold was applied to each of the assessment criteria. This implies that the significance concept is equated with recognising the value of each of these individual attributes in relation to other surf breaks in the regional resource. Similar approaches are the norm for the identification of ecologically significant areas in New Zealand under RMA section 6(c). Candidate areas are assessed against a set of criteria, each of which has a threshold, and areas qualifying under any one criterion are deemed significant (Davis *et al.*, 2016). However, as with summed score methodologies, a philosophical decision is required to set the significance threshold. In Taranaki, this was addressed by interpreting evidence of value as a score exceeding the mid-point of the rating scale, and defining the scale so that the mid-point equated with a 'moderate' importance rating (Orchard, 2017c). By definition, lower scores indicated a lower than moderate level of importance.

The two examples to date also used substantially different evidence bases, with Northland making use of an expert panel, and Taranaki demonstrating the potential to engage with local knowledge held in the wider community. However, the MCA methodologies employed could be applied to the assessment scores generated by either approach. As a consequence, these examples provide a useful contrast in considering the options available for gathering evidence for criteria based assessments, and analysing the results for management purposes.

Implications of the Different Approaches

In New Zealand's devolved resource management system, regional policy and plan review processes provide an important mechanism for giving effect to new national policy and objectives (Memon and Perkins, 2000). As such, the regional significance concept could assist with the recognition of surf breaks, as is needed in strategic planning, and impact assessment processes (Scarfe *et al*., 2009). Furthermore, a consistent treatment of regional significance would appear to be advantageous for the design of protection mechanisms, especially those that have wide applicability. Despite this, the case comparisons presented here show that there is potential for different stakeholders to have contrasting views about what constitutes regional significance, and this needs to be resolved in the design of assessment methodologies.

It is important to note that while hierarchical classifications are being explored by some authorities, others have extended protection measures to all of the currently known surfing resources in the region as a simpler approach to addressing the NZCPS. This may be appropriate if it is deemed too complex or unnecessary to discern between levels of significance, for example, where there are relatively sparse surf resources in a region. Indeed, it can be observed that the trend towards criteria based assessments has been led by surf-rich regions in which there may be a perception of the need to protect only the best of the resource to a greater degree, potentially at the detriment of locations deemed to be of lesser importance. A blanket approach is conservative and precautionary, which is in line with the NZCPS and is certainly agreeable with environmental protection groups. It can however, be seen as impractical by management authorities and restrictive to those who ply their trade in the coastal environment.

This work has highlighted the implications of methodological choices in relation to their propensity to exclude surf breaks from recognition, and the basis for doing so. Although planning approaches based on recognising surf breaks of higher relative importance are a potentially useful mechanism, it is important that they are complementary to the wider objectives for sustainable surf resource management and meet the needs of the local community.

Information Sufficiency and Non-Disclosure of Sensitive Sites

In general, there is a lack of documentation to describe the current values and condition of New Zealand's surfing resources. A combination of community data, field measurements, and numerical modelling can assist in addressing these needs, and should be applied to all of the attributes that underpin important values. Decisions on how much information is required for a credible assessment are also an important consideration. This applies to any of the data collection processes that have been used to date including assessments made by expert panels and other small groups, or through the analysis of community data. In practice, this can be related to the minimum number of knowledge-holders required to make a robust assessment. This has the potential to influence the outcomes of classification processes such as the identification of regional significance status. It is likely to be a critical factor for the assessment of lesser known surf breaks in view of the difficulty obtaining information on the attributes of these locations.

Orchard (2017c) proposed that a 'data deficient' qualifier could be useful to denote situations where the information base was deemed insufficient for the purposes of the particular assessment. However, it is important that the use of a data deficient status triggers additional information gathering and is not equated with the surf break having been assessed and assigned a 'not significant' status. Importantly, this issue applies equally to the knowledge base of expert panels or inputs received from the wider community, and this illustrates that the transparency of the assessment is important. For example, where expert panels are used for rating surf breaks, the scores assigned by individual members could be accounted for independently, and variance in results dealt with in subsequent analysis to improve transparency. Although this approach has not been applied to date, it would help to identify knowledge gaps and lead to a more consistent treatment of data deficiency issues as has been explored for the analysis of survey data (Orchard, 2018). Another potential shortcoming of the expert panel approach is the difficulty in selecting experts who are knowledgeable in the key attributes that underpin community values from the perspective of the wider surfing community of the region.

A related issue concerns the non-disclosure of some surf resources by local knowledge holders who may prefer to keep the locations secret for reasons including that this may be the most effective way of ensuring their values are protected. This is particularly applicable to surf breaks with high wilderness values (Orchard, 2017c) which provide opportunities for uncrowded surfing experiences. It is likely to become increasingly important in the coming years due to the increasing trend in surf resource user numbers leading to higher demand for uncrowded locations. Orchard (2017c) related the likelihood of non-disclosure to the sensitivity of certain locations from the perspective of local knowledge holders and referred to these locations as 'locally sensitive breaks' (LSBs). Options to recognise LSBs could include a mechanism by which surf resources could be nominated for regional significance assessment outside of the plan review process, for the purpose of extending statutory protection where needed. Alternatively, they could be addressed through methods that do not rely on regional significance status. For example, a methodology could be developed similar to the 'silent file' approach used by Ngāi Tahu for culturally sensitive sites (Tau et al. 1990), that would not be discoverable on maps, or may include obscured data to indicate the presence of a valued location within a certain radius or length of coastline.

Atkin and Mead (2017) came to similar conclusions in considering the many examples of 'secret spots' that they became aware of in an assessment of surf breaks in Waikato. They also recognised the need to document the existence of these resources, yet avoid potential discord within the surfing community that is likely to arise through the exposure of lesser known surfing locations. To address this, they also recommended the creation of a separate planning category: Surf Breaks of Local Significance (SBLS). Atkin (2017) bookmarked the existence of the SBLS while concealing specific details of their location and maintaining their 'secret' status by specifying Known Surfing Coastlines

(KSC). The KSC function is to highlight sections of coast where surfing is known to be undertaken and/or possible. The approach provides an ambiguous and non-descript way of recording the existence of SBLS should management decisions concerning a section of coast be required. KSC were delimited and named by prominent geographical features along the coast, similar to the naming convention for nautical charts. The actual surfing area may be some distance offshore from the designated coastline (*e.g.*, an isolated rocky reef), however the GIS data provides the necessary information to inform the decision-making processes.

The SBLS term has also been used in Taranaki to refer to surf breaks that have been identified and mapped but fail to meet the qualifying criteria for SBRS (TRC, 2018). This reflects variation in the terminology being used to describe new ideas in the most recent developments. Despite this, the common threads of recognising locally sensitive sites and local levels of significance are important considerations for the development of a holistic approach to surf resources.

Transferability to Other Management Contexts

It is important to identify the specific objectives for which regional significance status has been designed to assist in New Zealand. The concepts described here have been primarily developed to address the policy requirements of the NZCPS due to its pivotal influence on the management context. An important aspect is that the resource management paradigm is characterised by an effects-based approach, and this depends on the recognition of resources and their values to inform evaluations of the adverse effects of proposed developments (Rennie, Orchard and Peryman, 2014). In this sense a surf break is a spatially explicit management area that has been recognised for direct protection, or to trigger the need for impact assessments to inform the design of development proposals. The concept of regional significance has evolved in this context for the purpose of generating information on the values that are present and may include the classification of surf breaks according to these values.

Although this case study has focused on application to the design of statutory protection methods such as those found in resource management plans, regional significance assessment could be useful to a wide variety of protection initiatives. These include the establishment of legally protected areas, consideration mechanisms for development proposals such as the requirement for consents and permits, in the identification of threats and preparation of impact assessments, and to inform non-statutory methods such as educational activities and signage.

CONCLUSIONS

Regional significance is a relatively new tool for surf break management. Due to differences in the timing of regional policy and plan review cycles, the progress to date has occurred incrementally in New Zealand. In a practical sense this provides an opportunity for other regions to review, learn from, improve and implement these new approaches. Conversely, inconsistencies between regions may increase the likelihood of implementation gaps from the perspective of achieving higher level objectives. In New Zealand, this has implications for the design of planning approaches for surfing resource management, particularly around the need for effective methods to achieve national policy objectives under the NZCPS. With regards to the role of regional significance status, these aspects are important to decisions on the inclusivity of surf break assessments in relation to different types of breaks, identification of the locations to be assessed, the basis for community participation, and specific details of the methodology to be applied such as the setting of significance thresholds. Additional aspects identified here, and which may be best dealt with outside of regional significance assessment, include the need to recognise Surf Breaks of Local Significance that may be the subject of non-disclosure by knowledge holders.

Further developments in the concept of regional significance are expected as other regions explore the topic and apply their own approaches. This will help inform questions around the need for consistency which requires ongoing evaluation of the strengths and weaknesses of new approaches, towards which this study is an important first step. Irrespective of the qualifying criteria for regional significance status, an important aspect of these methodological developments has been to generate much-needed baseline data on surf resources. This information is currently lacking for most surf breaks in New Zealand, which is typical worldwide, yet is essential for an understanding of the values at stake, and the effectiveness of measures for their protection.

ACKNOWLEDGMENTS

Thanks to the many people that have provided information pertinent to this research including the staff of management authorities who have provided documentation and useful perspectives, and others who have helped in the design and facilitation of regional assessments. Particular thanks to members of the public who participated in surveys and identified their significant surf breaks, and to the authors of previous research who have contributed valuable concepts.

LITERATURE CITED

Atkin, E.A., 2017. *Known surfing coastlines in the Waikato region.* Raglan, New Zealand: eCoast Marine Consulting and Research. *Letter Report*, WRC.

Atkin, E.A.; Gunson, M., and Mead, S.T., 2014. *Regionally significant surf breaks in the greater Wellington region.* Raglan, New Zealand: eCoast Marine Consulting and Research, 93p.

Atkin, E.A. and Mead, S.T., 2017. *Surf breaks of regional significance in the Waikato region.* Raglan, New Zealand: eCoast Marine Consulting and Research, 75p.

AC, 2016. *Auckland unitary plan, operative in part.* Auckland, New Zealand: Auckland Council, 36p.

BPRC., 2017. *Proposed Bay of Plenty regional coastal environment plan*. Tauranga, New Zealand: Bay of Plenty Regional Council, Version 9.1h.

Bhana, M., 1996. *New Zealand surfing guide*, *revised ed.* Auckland, New Zealand: Reed Books, 127p.

Congreso de la Republica Perú., 2013. *Ley de Preservación de las Rompientes apropiadas para la Práctica Deportiva*. Peru: Congreso de la Republica Perú, LEY Nº 27280.

Coombes, K., and Scarfe, B., 2010. *Draft Auckland regional policy statement background report – Surf breaks*. Auckland, New Zealand: Environmental Policy and Planning (ARC), 37p.

Yin, R.K., 2003. *Case study research: Design and methods*, *3rd ed*. Thousand Oaks, California: Sage Publications, 181p.*In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa/New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 1–12. Coconut Creek (Florida), ISSN 0749-0208.

Appendix C. Managing Issues at Aotearoa New Zealand's Surf Breaks

Publication details:

Mead, S.T. and Atkin, E.A., 2019. Managing Issues at Aotearoa New Zealand's Surf Breaks. In: Bryan, K.R. And Atkin, E.A. (Eds.), Surf Break Management in Aotearoa New Zealand. Journal Of Coastal Research, Special Issue No. 87, Pp. 13–22. Coconut Creek (Florida), ISSN 0749-0208.

Journal of Coastal Research	SI	87	13–22	Coconut Creek, Florida	2019

Managing Issues at Aotearoa New Zealand's Surf Breaks

Shaw T. Mead†* and Edward A. Atkin†‡

†eCoast Marine Consulting and Research
Raglan, New Zealand

‡University of Waikato
Hamilton, New Zealand

www.cerf-jcr.org

www.JCRonline.org

ABSTRACT

Mead, S.T. and Atkin, E.A., 2019. Managing issues at Aotearoa New Zealand's surf breaks. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 13–22. Coconut Creek (Florida), ISSN 0749-0208.

Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS) provides a legislative framework that identifies and calls for the protection of surf breaks of national and regional significance by "ensuring that activities in the coastal environment do not adversely affect the surf breaks" and by "avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks". While this is ground-breaking as the world's first environmental policy to specifically identify surf breaks as protected spaces, it has been somewhat toothless in its effectiveness because there are no clear, quantitative measures or guidelines describing the oceanographic or geomorphic characteristics of the coastal zone that contribute to the functionality of a surf break. This paper summarises our existing knowledge concerning surf breaks in New Zealand and highlights the management issues facing local communities and councils; it presents an example of an implemented management approach and the way forward with the recently completed national management guidelines for surfing resources, which are a world first.

ADDITIONAL INDEX WORDS: *Surf break management, surf break characterisation, national guidelines*.

INTRODUCTION

Surf breaks are unique and valuable components of the coastal environment. They have cultural, spiritual, recreational, and sporting value to in excess of 200,000 people in New Zealand (Graham, 2011; Sport and Recreation New Zealand, 2008). Surf breaks are becoming increasingly recognised in New Zealand coastal policy which is consistent with developments occurring internationally. An increased focus on mechanisms to protect surf breaks has resulted from numerous cases of degradation worldwide and a greater awareness of existing values (*e.g.*, Scarfe *et al*., 2009a, 2009b). The argument for protection of surf breaks recognises that a range of benefits are associated with these unique places. These values depend on the integrity of natural processes which influence surf break environments, and on a variety of aspects important to surf break users including accessibility and environmental health (Peryman and Orchard, 2013). Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS) provides a legislative framework that identifies and calls for the protection of surf breaks.

The scheduled 10-yearly revision of the NZCPS 1994 was undertaken in 2009 and included a comprehensive review process and input from stakeholder groups (Rosier, 2004, 2005; Young, 2003) including the Surfbreak Protection Society (SPS), a Society formed in 2006 and dedicated to the conservation of New Zealand's surf breaks. The process attracted considerable input from surfers and surfing organisations, and the resulting submissions provided recommendations for the definition of a "surf break" and provisions for surf break protection (Board of Inquiry, 2009a). These recommendations were largely adopted within the final NZCPS 2010 as Policy 16 (Department of Conservation, 2010).

Policy 16: Surf Breaks of National Significance:

Protect the surf breaks of national significance for surfing listed in Schedule 1, by:

(a) ensuring activities in the coastal environment do not adversely affect the surf breaks, and;

(b) avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks.

Schedule 1 of the NZCPS defines a surf break as:

> "*A natural feature that is comprised of swell, currents, water levels, seabed morphology, and wind. The hydrodynamic character of the ocean (swell, currents and water levels) combines with the seabed morphology and winds to give rise to a 'surfable wave'. A surf break includes the 'swell corridor' through which the swell travels, and the morphology of the seabed of that wave corridor, through to the point where waves created by the swell dissipate and become non-surfable. 'Swell corridor' means the region offshore of the surf breaks where ocean swell travels and transforms to a 'surfable wave'. 'Surfable wave' means a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the wave crest.*"

DOI: 10.2112/SI87-002.1 received 28 August 2019; accepted in revision 6 September 2019.
*Corresponding author: s.mead@ecoast.co.nz

Policies 13 and 15 of the NZCPS (2010) are also relevant to surf break protection with regard to their associated natural character and the natural features that comprise them, respectively. While there are 17 surf breaks currently listed as nationally significant, all surf breaks can be considered unique in terms of natural character and the natural features that they are comprised of (*e.g.*, rocky reefs, headlands, ebb-tidal deltas, and open coast beach environments) and will fall in to a significance category (Orchard *et al.*, 2019).

The 17 Surf Breaks of National Significance are listed in Schedule 1 of the NZCPS, and regionally significant surf breaks are currently being identified by Regional and Local authorities that are responsible for implementing the NZCPS. While this is ground-breaking as the world's first environmental policy to specifically identify surf breaks as protected resources, it is somewhat toothless in its effectiveness because there have been no clear, quantitative measures or guidelines describing the oceanographic or geomorphic characteristics of the coastal zone that contribute to the functionality of a surf break.

Furthermore, surf breaks are an important physical component of the marine ecosystem that are comprised of a variety of interdependent variables. At present there is little to no data pertaining to either the existing wave-quality and breaking patterns, or the drivers (*e.g.*, wave climate, sediment supply, hydrodynamics) that create and affect these nationally and regionally significant assets, or socio-economic measures such as user numbers, duration of quality surfing conditions, and other relevant data. Thus, it has historically been difficult to fulfil the objectives of the Policies in the NZCPS that relate to surf breaks.

This lack of characterisation of New Zealand surf breaks for management purposes has led to controversy with respect to surf break management, and uncertainty with respect to potential and actual impacts in the absence of a thorough understanding of what features of a surf break may be impacted and what should be protected.

This paper outlines the existing knowledge with respect to the characterization and monitoring of surf breaks in New Zealand to date and briefly describes some of a number of surf break management issues that have arisen since the incorporation of surf breaks into the NZCPS. An example of an implemented management approach that was developed for the management and protection of surf breaks is then presented, which then leads into the development of structured guidelines for the management of New Zealand's surfing resources (Atkin *et al.*, 2019a, b).

EXISTING KNOWLEDGE – SURF BREAK CHARACTERISATION PARAMETERS

There are a variety of parameters that are used to characterize surf breaks. These include:

- Surf break type;
- Wave height range;
- Peel angle;
- Ride length;
- Breaking intensity;
- Tides and currents;
- Wind;
- Bathymetry/surf break components;
- Swell corridor, and;
- Surfable days per year.

Surf Break Type

There are 5 geomorphic types of surf break: rocky/coral reef, point break, rock ledge, river/estuarine delta and sand beach (Mead, 2000; Scarfe, 2008). Consideration of the surfbreak geomorphology also indicates the type of substrate that it is comprised of, which in turn can provide an indication of potential impacts that could affect the break. For example, a river/estuarine delta break comprised of sand could be negatively impacted by activities relatively distant from the break itself that change sediment supply and/or the tidal prism (which in turn impacts on tidal currents that are part of the governing mechanisms of delta formation). The temporary loss of one of Europe's iconic delta breaks, Mundaka in Spain, has been linked to the dredging of the estuary (Liria *et al.*, 2009, Murphy and Bernal, 2008). Similar impacts on one of New Zealand's 17 Surf Breaks of National Significance, the Whangamata Bar (i.e. an ebb-tidal delta), may also be associated with changes to the tidal prism and maintenance dredging for a new marina (see Atkin *et al.*, 2013).

Wave Height

Most surf breaks have a range of incident wave heights that result in optimum surfing conditions. At all breaks, waves must be of a certain height for them to be surfable. Conservative thresholds for a minimum wave height of 0.5 m (Mead *et al.*, 2004) and 0.75 m (Black *et al.*, 2004), in combination with a wave period of ≥6 seconds have been previously put forward, although these are generalizations and can vary from break to break depending on factors such as the seabed gradient and composition. Atkin and Greer (2019) provide discussion around minimum surfable wave height relevant to numerical model applications for surf break assessments. A minimum wave height of 0.75 m was deemed appropriate for each of the surf breaks considered. Many breaks will also have a maximum wave height, after which they become unsurfable, while big wave surf breaks often do not start to break until the waves are larger than a certain height.

Peel Angle

The peel angle has been defined as the angle between the trail of the broken white water and the crest of the unbroken part of the wave as it propagates shoreward (Hutt, 1997; Hutt *et al.*, 2001; Walker *et al.*, 1971, 1972). Peel angle is proxy to the rate at which the breaking part of the wave translates along the crest, or the speed at which a wave is breaking.

A wave that breaks along the length of its crest simultaneously has a peel angle of zero degrees; known as a 'close-out' by surfers. If there is no translation of the breaking part of the wave along the crest at all, then the peel angle is 90°. A wave with a small peel angle will break faster than one with a high peel angle. Peel angles of 35-75° are generally preferred for surfing (Hutt *et al.*, 2001; Mead, 2000).

Ride Length

The length of a surfable wave can be considered an important aspect of surfing. The preference of long, low breaking intensity waves over short high breaking intensity ones, or *vice versa* is irrelevant, and a common generalisation as there are many examples of long, high breaking intensity waves (*e.g.*, Skeleton

Bay in Namibia; Mundaka, Spain, Desert Point, Lombok, Indonesia). What is important is to be able to measure the length of surfable waves to establish a baseline characteristic.

Breaking Intensity

Breaking intensity refers to how 'hard' a wave breaks. Traditionally, four breaker types are used to classify wave-breaking intensity (spilling, plunging, collapsing and surging - Battjes, 1974), with waves in the spilling and especially the plunging categories being desired for surfing. When a spilling wave breaks, the crest crumbles down the face of the wave without an open vortex; the vortex is referred to as the 'tube' or 'barrel' by surfers (Figure 1). Spilling waves are therefore considered 'soft' or 'fat' by surfers as they do not provide very steep faces for generating speed for manoeuvres, or getting inside the vortex and being 'tubed' or 'barrelled'.

Mead and Black (2001a) recognised that there is a wide range of wave shapes in the plunging category, and developed a method to characterize the wave breaking intensity, which is a function of the seabed gradient that the wave propagates over prior to breaking. Mead and Black (2001a) developed a linear relationship to predict a plunging wave's 'vortex ratio' (after Sayce, 1997; Sayce *et al*., 1999) and characterize a wave's breaking intensity. The vortex ratio is the length to width ratio of the area underneath the breaking part of the wave (Figure 1). As the vortex ratio decease towards unity, the tube shape becomes more circular and less elongate, and breaking is more intense. Breaking waves with vortex ratios less than 1.6 are likely to collapse; waves with vortex ratios larger than 3 tend towards spilling (Mead and Black, 2001a).

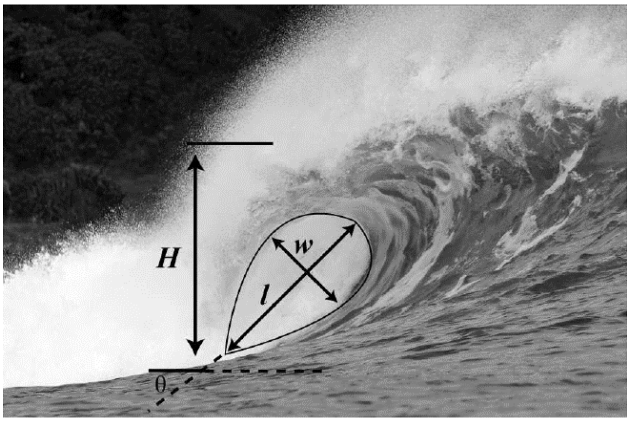


Figure 1. Breaking intensity determined by the vortex ratio (Sayce, 1997; Mead and Black, 2001c), is the ratio of the wave vortex width (w) over the length (l) (from Mead and Borrero, 2017).

Tides and Current

Water level (tides) and currents can have profound impacts on surf breaks; for example, some breaks may only be surfable during low tide, some only during high. The tidal elevation can also affect the amount of wave energy that reaches a break due to the effects of refraction.

The effects of currents on a surf break, which are often associated with tides, range from impacts on the height and steepness of a wave, through to safety, access, whether there will be waves breaking or not and configuration of the seabed (*e.g.*, Phillips, 2004). Currents running against propagating waves tend to shorten the wavelength and consequently increase wave height (since the period remains the same) and breaking intensity; and *vice versa* when currents run in the same direction as wave propagation (Peregrine and Jonsson, 1983).

Wind

Winds both generate waves and affect the quality of the waves at a surf break, depending on strength and direction; the latter is important for surf break characterization. Local winds can play an important role in creating surfable waves and/or degrading surfing wave quality, depending on wind strength and direction (Galloway *et al*., 1989; Pratte *et al*. 1989; Schrope, 2006). The ideal wind is light to non-existent for the cleanest conditions (Figure 2), however certain onshore and cross shore wind conditions are targeted by some high-performance surfers to train for and perform specific manoeuvres (Atkin *et al*., 2019a).

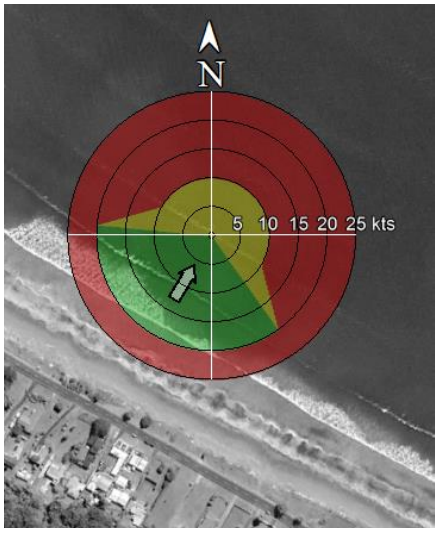


Figure 2. 'Wind-rose' overlaid on aerial photo depicting the effects of local wind strength and direction on surfing waves (Modified from Walker, 1997). Green, yellow and red colours indicating areas most favourable, favourable and unfavourable for surfing, respectively, as a function of wind direction and speed (in knots). Incident waves in this example are from the northeast, and a direct offshore (grey arrow) is from the southwest.

Bathymetry/Surf Break Components

Bathymetry is a critical component of surf break characterization. It is the shape of the seabed that has the most influence on the form of breaking waves, determining both wave steepness/intensity (Battjes, 1974; Couriel *et al*., 1998; Mead, 2000; Mead and Black, 2001b; Peregrine, 1983; Sayce, 1997); and peel angle (Hutt, 1997; Hutt *et al*., 2001; Walker, 1974a). Analysis of over 40 surf break bathymetries in the Pacific, Australasia and Indonesia identified a series of commonly occurring geomorphic components from which surf breaks are comprised, namely: ramp; platform; wedge; ledge; focus; ridge; and, pinnacle (Mead, 2000; Mead and Black, 2001b, c). It is the combinations of these components and how they modify wave propagation and breaking that primarily accounts for the wave quality at a surf break (Mead and Black, 1999; Mead and Black, 2001a). Surf break components range in scale from small local features (*e.g.*, a pinnacle) to large offshore components distant from the surf break, but within the swell corridor.

Swell Corridor

As defined in the NZCPS (2010), the swell corridor is "the region offshore of a surf break where ocean swell travels and transforms to a 'surfable wave'. Long period surface waves can 'feel' the seabed at depths approximately twice that of their wavelength, which in some cases occurs at the edge of the continental shelf. As a result, the swell corridor for a particular break can be extensive (Figure 3). Understanding the spatial extent of the swell corridor is of particular importance where offshore activities such as seabed mining, wind farms and aquaculture are proposed.

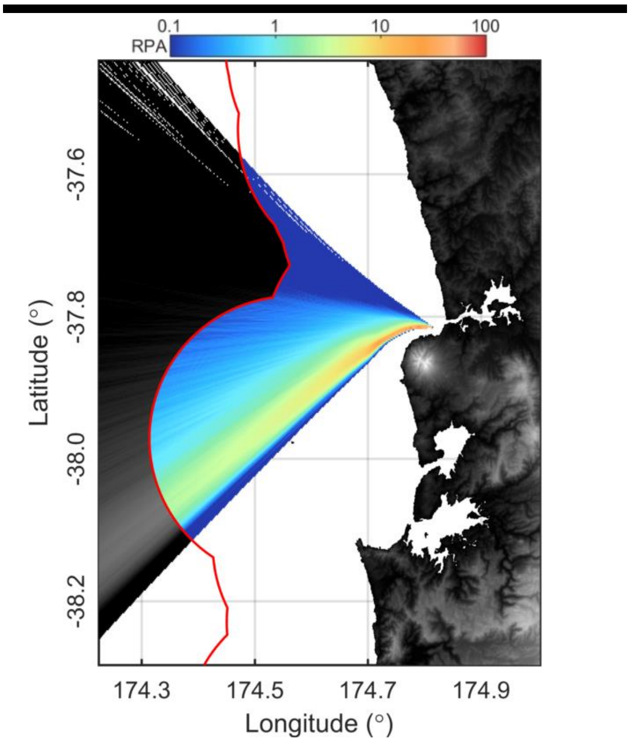


Figure 3. Swell corridor presented as Relative Percent Activity (RPA) determined by streamlines from numerical model output for Manu Bay. Data outside the territorial sea (red line) shown in greyscale (Atkin and Greer, 2019).

Surfable Days Per Year

Some surf breaks, such as Manu Bay in Raglan, New Zealand, can be surfed consistently throughout the year, while others, such as Orere Point in the Firth of Thames, New Zealand, may only host surfable waves a few days or weeks per year. By determining thresholds for surfable wave heights and periods at a surf break (Black *et al*., 2004; Mead *et al*., 2004), and analysing long-term coincident wind and wave data, the number of surfable days per year can be determined. This can be further refined by identification of the swell corridor to determine the wave events that can feasibly reach a particular break (Atkin and Greer, 2019).

Scarfe, *et al*. (2009a) provides a comprehensive review of research-based surfing literature which details many of the characteristics of surf breaks described above. Further guidance on the characterization of surf breaks is provided in the Management Guidelines for Surfing Resources (Atkin *et al*., 2019a, b), which is discussed in more detail below.

EXISTING KNOWLEDGE – CHARACTERISATION OF NEW ZEALAND'S NATIONALLY AND REGIONALLY SIGNIFICANT SURF BREAKS

At the most basic level, the various New Zealand Surf Guides (Bhana, 1996; Morse and Brunskill, 2004; Rainger, 2011) have identified the majority of New Zealand's popular surf breaks, and provide broad characterization in terms of the type of break, the best conditions that the break works in (*i.e.*, swell height, swell direction, tidal phase, wind direction), and additional information such as access and potential threats (*e.g.*, sharks, heavy localism, etc.). Indeed, in the absence of quantified investigations, the New Zealand Surf Guide (Morse and Brunskill, 2004) was used to identify the 17 surf breaks that were incorporated into the NZCPS as nationally significant (*i.e.*, those that scored 9/10 or greater on the 'stoke rating', with 2 lower scoring breaks added for other particular features, such as Papatowai being a premier big-wave break).

However, while these guides are very useful for identifying breaks and providing a basic understanding of the break's characteristics, they are subjective and do not provide quantitative information. Quantitative information is critical for the successful management of surf breaks, since without it there is no ability to measure change, such as those associated with coastal developments and activities within the Coastal Marine Area and swell corridor. In the absence of quantitative information, management issues at surf breaks often become subject to opposing opinions without resolution, which does little for their protection and the principles of sustainable development/management.

While the fundamentals of quantitative surf break characterization date back to the early 1970's (*e.g.*, Silvester, 1975; Walker, 1974a, b; Walker and Palmer, 1971; Walker *et al*., 1972), it was not until the mid-1990's that Walker's work was significantly advanced through the Artificial Reefs Programme (the ARP).

The ARP was administered through the Center of Excellence in Coastal Oceanography and Marine Geology, a joint center with the New Zealand's University of Waikato and the National Institute of Water and Atmospheric Research. A series of MSc and PhD studies further developed Walker's seminal studies, which form the basis of surf science (for comprehensive reviews of the existing body of surf science see Mead and Borrero, 2017; Scarfe *et al*., 2009a). These studies provided quantitative data and methodologies that have been applied to the characterization of surf breaks such as wave peel angles (Hutt, 1997; Hutt *et al*., 2001), wave breaking intensity (Mead and Black, 2001a; Sayce, 1997), surf break functional components and seabed morphology (Mead, 2000; Mead and Black, 1999; Mead and Black, 2001b,c), and remote sensing techniques to quantify surfing wave characteristics (Moores, 2001; Scarfe, 2002). As a result of the ARP and consequent research of surf breaks, New Zealand remains the world-leaders in the area of surf science.

Raglan

The point breaks at Raglan on the Waikato west coast are without doubt the most intensively studied surf breaks in New Zealand, if not the world. Surf science studies commenced in Raglan in the mid-1990's with the instigation of the ARP. As described above, the ARP studies, which were mostly undertaken on the Raglan point breaks, provided quantitative data and methodologies that have been applied to the characterization of surf breaks globally.

As a result, the bathymetry of all Raglan's surf breaks has been repeatedly surveyed, and side-scan sonar surveys and diver surveys have also been carried out (*e.g.*, Atkin *et al.*, 2017; Hutt, 1997; Mead, 2000; Phillips 2004: Phillips and Mead, 2008; Sayce, 1997; Scarfe, 2002). These data have been analysed to create a documented record of seabed gradients and breaking intensities (Mead and Black 2001a), and the sand/rock interface, and surf break components of the Raglan Points (Mead, 2000; Phillips, 2004; Sayce, 1997; Scarfe, 2002).

Wave peel angles have been measured from the outer break (Outsides) through to the innermost break (Manu Bay) (Hutt, 1997). Wave and current data have been recorded through multiple deployments (Hutt, 1997; Sayce, 1997; Phillips, 2004). Much of these data have also been used for the development of hydrodynamic and sediment transport numerical models (Hutt, 1997; Mead and Phillips, 2007; Phillips, 2004; Phillips and Mead, 2008).

As well as leading to the detailed characterization of surf breaks, these studies advanced many areas of surf science; *e.g.*, Hutt *et al.*'s (2001) progression of the Walker (1974) surfer skill rating scheme (Table 1 and Figure 4).

Other than previous studies and the characterization of Raglan's point breaks, prior to the development of the management guidelines (Atkin *et al.*, 2019a, b) there have been few studies to characterize New Zealand's nationally and regionally significant surf breaks (see Kilpatrick, 2005 – Aramoana; Mead *et al.*, 2011 – Maori Bay), unless the break has been subject to some kind of potential or actual impact from a proposed development or coastal activity (Atkin *et al.*, 2017, 2019a; Hume *et al.*, 2019).

SURF BREAK MANAGEMENT ISSUES

At least 28 New Zealand surf breaks have become the subject of debate due to proposed developments in the past few decades, including 6 of the 17 Nationally Significant surf breaks listed in the NZCPS (Figure 5):

- Whangamata Bar – marina development;
- Aramoana and Whareakeake – nearshore dredge disposal;
- Waiwhakiaho – waste-water outfall;
- Manu Bay – breakwater construction, and;
- Mangamaunu – cycleway revetment.

Table 1. *Rating of the skill level of surfers. Ratings are independent of surf break quality or the degree of difficulty of waves (Hutt et al., 2001).*

Rating	Description of Rating	Peel Angle Limit (deg)	Min/Max Wave Height (m)
1	Beginner surfers not yet able to ride the face of a wave and simply moves forward as the wave advances.	90	0.70 / 1.00
2	Learner surfers able to successfully ride laterally along the crest of a wave.	70	0.65 / 1.50
3	Surfers that have developed the skill to generate speed by 'pumping' on the face of the wave.	60	0.60 / 2.50
4	Surfers beginning to initiate and execute standard surfing manoeuvres on occasion.	55	0.55 / 4.00
5	Surfers able to execute standard manoeuvres consecutively on a single wave.	50	0.50 / >4.00
6	Surfers able to execute standard manoeuvres consecutively. Executes advanced manoeuvres on occasion.	40	0.45 / >4.00
7	Top amateur surfers able to consecutively execute advanced manoeuvres.	29	0.40 / >4.00
8	Professional surfers able to consecutively execute advanced manoeuvres.	27	0.35 / >4.00
9	Top 44 professional surfers able to consecutively execute advanced manoeuvres.	Not reach	0.30 />4.00
10	Surfers in the future	Not reach	0.3 / >4.00

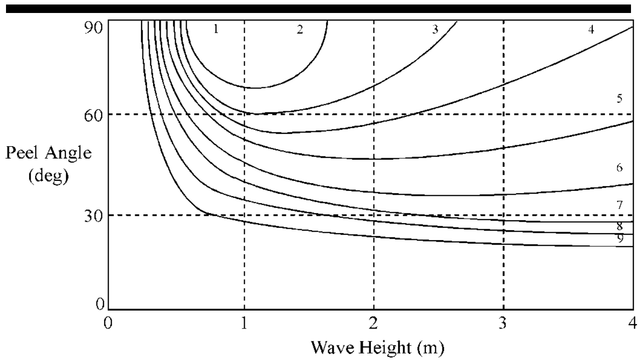


Figure 4. Classification of surfing skill against peel angle and wave height (Hutt *et al.*, 2001).

Management issues at surf breaks in New Zealand have ranged from a proposed breakwater extension at Takapuna boat ramp to allow for better access to view the America's Cup races in the late 1990's (Black *et al*., 1998) with the potential to negatively impact Takapuna Reef, to potentially significant degradation of surfing quality due to an airport extension at Lyall Bay, Wellington (DHI, 2015) and a port expansion project in Otago (Atkin and Mead, 2012), to user conflicts due to increasing usage of the surf zone (Hume *et al*., 2019). Hume *et al*.'s (2019) companion paper in this special issue, "An overview of changing usage and management issues in New Zealand's surf zone environment", presents details of case studies describing management issues at several surf breaks and surfing areas, and further case studies are presented in Atkin *et al*. (2019a).

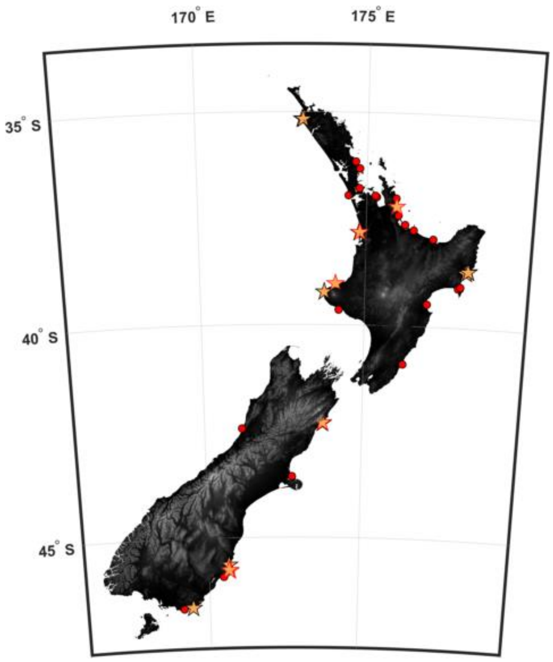


Figure 5. New Zealand's surf breaks that have been impacted, or potentially impacted on, by proposed and implemented coastal developments and activities (red dots). Of the 17 Surf Breaks of National Significance scheduled in the NZCPS (2010; stars), 6 have been involved in disputes due to potential and/or actual impacts from development (red stars).

Conflicts of interest has led to appeals to Environment Court, facilitated mediation and High Court Injunctions concerning coastal activities. With few exceptions, a lack of quantified data characterizing the surf breaks under threat, as well as a lack of guidance on how to characterize, assess and manage surf breaks have been a focal point of legal proceeding. Without relevant data and clear guidance, Assessments of Environmental Effects (AEEs) that have accompanied resource consent applications have either not taken potential effects on surf breaks into account or have not assessed the potential impacts sufficiently. As a result, councils and local communities have been unable to gain a clear understanding of the potential and actual issues associated with proposed developments and activities on surf break amenity, which has resulted in conflicts between stakeholders and opposition by the SPS and local boardrider clubs.

Even so, in many cases the Resource Management Act 1991 process has resulted in positive management outcomes, including the development of implemented management approaches to allow for sustainable development, many of which have been incorporated into the Management Guidelines for Surfing Resources (Atkin *et al*., 2019a, b).

IMPLEMENTED MANAGEMENT APPROACHES

As noted in the introduction, Policies 13, 15 and 16 of the NZCPS (2010) are all relevant to surf break protection, and so while there are 17 surf breaks currently listed as of national importance, all surf breaks can be considered important in terms of natural character and the natural features that they are comprised of. As a result of the recognition of surf breaks as in policy and as natural features, often with significant natural character value and significant social, economic and cultural value, sustainable management approaches have had to be developed in order for new coastal activities and developments to proceed.

Port of Otago

A good example of an implemented management approach is that applied by Port Otago Ltd (POL) for the 'Project Next Generation', a capital and maintenance dredging project to use existing nearshore disposal sites at Aramoana and Heyward's.

Disposal of material dredged to maintain the entrance channel began at Aramoana (aka The Spit) in the early 1980's, while disposal at the Heyward's site coincides with the development of the port in the 1860's. Disposal of dredge material at the Heyward's site has the potential to impact on Whareakeake (aka Murderer's) wave quality due to wave focusing/defocusing and/or dispersion/splitting because the site is located in its' swell corridor (Figure 6). The Aramoana dredge material disposal site is located closer to shore and disposal at this site has the potential to impact on wave quality both through interacting with the waves propagating through its' swell corridor, as well as changes to the local bathymetry due to sediment moving shoreward (Figure 6). Both Whareakeake and Aramoana are categorized as Surf Breaks of National Significance in the NZPCS (2010).

In 2012, POL applied to increase the nearshore disposal volumes for both nearshore disposal sites to assist with channel deepening during periods when the sea conditions were too rough to dispose of material at the offshore site (known as 'A0'). This raised concerns with some local surfers and consequently the Surfbreak Protection Society (SPS) due to potential impacts on Aramoana and Whareakeake.

In the early 1980's, when nearshore disposal began at the site, some of the best surfing conditions were reportedly experienced at Aramoana. However, early in the 21st century there was a general concern that Aramoana was no longer providing the high-quality surfing waves that it had in the past. Anecdotal evidence suggested that continual addition of sand not only impacted the secondary focusing processes (of the nearshore mound; the ebb-tidal delta is responsible for the primary wave focusing at the break – Atkin and Mead, 2012), but that the embayment had become over-full with sand forming a large shallow platform in the nearshore; this resulted in 'close-out' surfing conditions during bigger swell conditions.

Following an appeal by the SPS when the consent for increased disposal quantities was initially granted, Environment Court was avoided through an agreement reached during pre-Hearing mediation. The agreement included a 3-year resource consent with greatly reduced disposal at the Aramoana site, and extensive monitoring and modelling for reassessment of the potential and actual impacts on the 2 Surf Breaks of National Significance.

A working party comprising of representatives from Te Runanga Otakou (representing the hapū of Ōtākou marae on the Otago Peninsula), Kati Huirapa Runanga ki Puketeraki (representing Karitane and extending from Waihemo to Purehurehu), Department of Conservation, Otago Regional Council, Surfbreak Protection Society, South Coast Board Riders Association, Aramoana Conservation Trust and POL worked together throughout the 3-year temporary consent to determine the impacts of nearshore disposal at Aramoana. The consent's monitoring conditions included:

- bathymetric surveys of the disposal sites,
- visual photographic records of surf conditions at Aramoana and Whareakeake,
- beach profile surveys,
- benthic monitoring of the Heyward Point and Aramoana disposal sites,
- rocky reef monitoring in vicinity of disposal sites, and
- wave monitoring of the Heyward and Aramoana disposal grounds.

Although not specified in the consent conditions, the working party decided that no dredge material would be placed at Aramoana for the first 2 years. During this time, it was perceived by all parties involved that surfing conditions had improved at Aramoana, which helped develop an effective monitoring scheme with trigger levels based on bathymetric contours of the beach.

Similar trials and follow up investigations of the Heyward's disposal site led to expansion of the disposal site to provide flexibility for the disposal of materials that are not readily transported (*i.e.*, rock) and ensure the morphology of the disposal mound had a positive impact with respect to focusing waves towards Whareakeake, as well as a maximum mound height to ensure that wave breaking and consequent wave-splitting did not occur. Through the approach described above, a set of conditions were developed that have been incorporated into the 25-year consent (granted in 2017) for maintenance dredge disposal at the 2 sites that fulfils Policy 16 of the NZCPS.

Port of Lyttleton

Similar to the issues associated with the Otago Harbour entrance channel, facilitated mediation allowed for agreement between stakeholders for maintenance dredging activities at Port Lyttleton's entrance channel. The conditions included the establishment of a Surfing Liaison Group to enable communication and information sharing between stakeholders and the applicant; water quality monitoring to determine the effects of fine suspended sediments on water quality at the surf break known as Taylor's Mistake, some ~5 km from the maintenance disposal site; surfing wave quality monitoring through a remote camera system; and, bathymetric surveys. The monitoring will inform the adaptive management plan, so that changes to the dredging and disposal scheme can be applied should negative impacts be detected.

For example, should water quality deteriorate at Taylor's Mistake during disposal when onshore winds over a particular speed are blowing, dredging and disposal would no longer be carried out during these conditions).

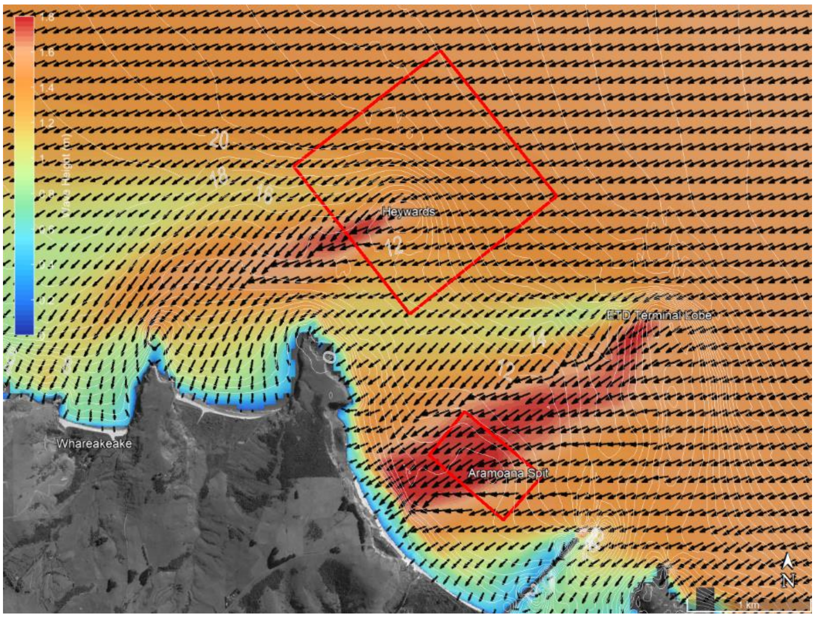


Figure 6. Swell wave height and direction (black arrows) at the entrance to Port Otago, with bathymetric isobaths (white) and modified dredge spoil disposal sites (red). Wave height focussing apparent on the terminal lobe of the Ebb Tidal Delta (ETD), Aramoana and Heyward Point disposal sites.

MANAGEMENT GUIDELINES FOR SURFING RESOURCES

Together with the surf break research that has been undertaken in New Zealand, the development and implementation of management approaches for surfing resources, such as those applied in these case studies presented in this manuscript, have culminated in the *Management Guidelines for Surfing Resources* (Atkin *et al*., 2019a). The guidelines provide background information and specific methodologies to assist in the sustainable management of New Zealand's surfing resources. The guidelines are aimed at assisting:

- authorities charged with implementing policies and plans.
- resource users and applicants to manage expectations and responsibilities with respect to resource consent requirements where proposed activities may affect surfing resources.
- stakeholders to understand how developments might affect the amenity value of surf breaks and the responsibilities of those proposing the developments.

The guidelines were developed as part of a Ministry of Business, Innovation and Employment (MBIE) funded project that aimed to build a knowledge base on surf breaks and to develop management guidelines to support the effective implementation of the NZCPS. The guidelines provide: information on the legislative and social context of surf breaks; an understanding of the physical characteristics of surf breaks and how they function; a description of factors that can compromise their amenity value; specific methodologies for management of surfing resources for authorities and consent applicants; information to assist with the identification, study, monitoring and sustainable management of surf breaks (Atkin *et al*., 2019a).

The guidelines also aim to manage the expectations of resource users and developers with respect to consent/permitting requirements where proposed activities are likely to affect access to, and the amenity value of surf breaks. The guidelines provide stakeholders with greater clarity on how activities in the coastal environment may affect a surfing resource and the responsibilities of those undertaking the activities (Atkin *et al*., 2019a).

The guidelines provide specific direction for authorities responsible for management of surfing resources, as well as for resource users and consent applicants who need to assess the potential impact of a development on the amenity value of a specific surf break(s) as part of a consent application. The first set of steps are designed to support council officers identifying, mapping and characterising surf breaks in their region, while these are expanded on for explicit applications for resource users and consent applicants for specific breaks. Threats and risk assessment guidance is provided to facilitate prioritising resources and preparing a "watch list" of surf breaks. Guidance is also given to managing authorities on incorporating surf break protection into policy and plans.

An important aspect that has been highlighted in this paper is the application of appropriate measures to characterize surf breaks and determine potential and actual impacts. The guidelines provide direction on the appropriate types of assessments for all stakeholders, as well as methodologies to undertake characterization, baseline studies, monitoring, threats and risk assessment, cultural impact assessment and the development of meaningful conditions of consents. Furthermore, the guidelines provide a large volume of information applicable to the management of surfing resources, from the principles of surf science through to links to resources detailing engagement with Māori, the indigenous people of Aotearoa New Zealand, which address our collective obligations under the Treaty of Waitangi, RMA (1991) and NZCPS (2010)

An important feature of the guidelines is the direction provided on assessment of threats and risks (Atkin *et al*., 2019a, b). While the general characterization of a surf break can be followed verbatim, the important aspects that need to be considered when proposing a coastal development or activity are directly related to the type of threat and the magnitude of the risk associated with it.

The Management Guidelines for Surfing Resources are a world first and fill a gap in environmental management in New Zealand. It is expected that the guidelines will be broadly, if not directly, applicable to the management of surfing resources worldwide. Even so, it is important to be cognizant that the guidelines are a 'living document', which will continually undergo review and updating, with plans for annual evaluations and 5 yearly revisions – or as and when required as more advanced information, understanding and data collection techniques evolve. There remain several aspects of surf break management that require refining and development (for example, development of the regional significance concept for surf break management in New Zealand – Orchard *et al*., 2018). The guidelines represent a major milestone and foundation resource for the management of surfing resources in New Zealand and around the world.

CONCLUSIONS

Historically, management issues with surf breaks, especially in the form of potential impacts from proposed activities and developments in the coastal zone, have been hard to address due to both a lack of quantified data characterizing surf breaks and a lack of guidance on managing the issues. The development of the Management Guidelines for Surfing Resources has largely contributed to addressing these issues, which now provide all stakeholders a structured pathway to ensure the sustainable management of our valuable surfing resources.

It is expected that the Management Guidelines for Surfing Resources in New Zealand will make the RMA (1991) resource consenting processes easier to follow and reduce the escalation to Environment Court appeals, meditation and other legal and social conflict. The Guidelines are a world-first and are a result of New Zealand being the most advanced country globally in terms of surf science and surf break conservation and a product of this experience and knowledge. The Guidelines could inform surfing resource management practices in other countries, albeit with site specific modifications as required.

ACKNOWLEDGEMENTS

This paper has been developed with the support of a Ministry for Business, Innovation and Employment (Hikina Whakatutuki) funded research grant "Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance."

LITERATURE CITED

Atkin, E.A.; Bryan, K.; Hume, T.M.; Mead, S. T., and Waiti, J., 2019a. *Management Guidelines for Surfing Resources*. Raglan, New Zealand: Aotearoa New Zealand Association for Surfing Research, 114p.

Atkin, E.A.; Mead, S. T.; Bryan, K.; Hume, T.M., and Waiti, J., 2019b. Management Guidelines for Surfing Resources. *Proceedings of the Coasts and Ports 2019 Conference* (Hobart, Australia).

Atkin, E.A. and Greer, D., 2019. A comparison of methods for defining a surf break's swell corridor. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 70–77.

Atkin, E.A.; Greer, D.; and Pickett, V., 2013. Whangamata ebb tidal delta morphology and wave breaking patterns. *Proceedings of the Coasts and Ports 2013 Conference* (Sydney, Australia), 18-22.

Atkin, E.A.; Gunson, M.; and Mead, S.T., 2014. *Regionally significant surf breaks in the greater Wellington region.* Raglan, New Zealand: eCoast Marine Consulting and Research, 93p.

Atkin, E.A. and Mead, S.T., 2012. *The impact of Otago Harbour spoil deposition on NZCPS 2010 protected surf breaks: Aramoana (Spit Beach), Whareakeake Bay (Murderers) and Karitane Point.* Raglan, New Zealand: eCoast Marine Consulting and Research.

Atkin, E.A.; Mead, S.T.; Bryan, K.; Hume, T.M., and Waiti, J., 2017. Remote sensing, classification and management guidelines for surf breaks of national and regional significance. *Proceedings of the 23th Australasian Coasts and Ports Conference* (Cairns, Australia).

Bhana, M., 1996. *New Zealand Surfing Guide*, *revised ed.* Auckland, New Zealand: Reed Books, 127p.

Black, K.P.; Beamsley, B.; Johnson, D.; Mead, S.T., and Mathew, J., 2004. *Boscombe surfing reef detailed design: Field data and initial design report.* Raglan, New Zealand: ASR Ltd. *Design Report*.

Black, K.P.; Mead, S.T., and Hutt, J.A., 1998. *Takapuna Boat Ramp: Surfing impact assessment and reef feasibility study.* Hamilton, New Zealand: University of Waikato, Department of Earth Sciences. *Technical Report.*

Board of Inquiry, 2009. *Proposed New Zealand coastal policy statement 2008, Volume 1: Findings, recommendations and recommended New Zealand coastal policy statement (2009).* Wellington, New Zealand: Department of Conservation, 57p.

Borrero, J.C.; O'Day, C., and Rifai, J., 2019. Application of Rip Curl SearchGPS watch data for analysing surf breaks. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 55–69.

Couriel, E.D.; Horton, P.R., and Cox, D.R., 1998. *Supplementary 2-D physical modelling of breaking wave characteristics*. Gold Coast, Australia: Water Research Laboratory, *Technical Report 98/14*, 117p.

Department of Conservation, 2010. *New Zealand coastal policy statement 2010.* Wellington, New Zealand: Department of Conservation, 30p.

DHI, 2015. *Wellington airport runway extension surf break impact assessment*. Auckland, New Zealand: DHI Water and Environment Ltd., *Technical Report*, 99p.

Galloway, G.S.; Collins, M.B., and Moran, A.D, 1989. Onshore/Offshore Wind Influence on Breaking Waves: An Empirical Study. *Coastal Engineering*, 13: 305–323.

Graham, S., 2011. Sport New Zealand's young people's survey 2011 – In-depth report. https://www.srknowledge.org.nz/researchproject/sport-new-zealands-young-peoples-survey-2011-in-depth-report/.

Hume, T.M.; Mulcahy, N., and Mead, S.T., 2019. An overview of changing usage and management issues in New Zealand's surf zone environment. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 1–12.

Hutt, J.A., 1997. Bathymetry and wave parameters defining the surfing quality of five adjacent reefs. Hamilton, New Zealand: University of Waikato, Master's thesis.

Hutt, J.A.; Black, K.P., and Mead, S.T., 2001. Classification of surf breaks in relation to surfing skill. *Journal of Coastal Research,* Special Issue No. 29, 66-81.

Kilpatrick, D., 2005. Determining surfing break components at Aramoana Beach, Dunedin. Dunedin, New Zealand: The University of Otago, Honours dissertation, 68p.

Liria, P.; Garel, E., and Uriarte, A., 2009. The effects of dredging operations on the hydrodynamics of an ebb tidal delta: Oka estuary, northern Spain. *Continental Shelf Research*, 29, 1983-1994.

Mead, S.T., 2000. Incorporating high-quality surfing breaks into multi-purpose offshore reefs. Hamilton, New Zealand: University of Waikato, Ph.D. dissertation.

Mead, S.T. and Black, K.P., 1999. Configuration of large-scale reef components at a world-class surfing break: Bingin reef, Bali, Indonesia. Proc. *Proceedings of the Australasian Coasts and Ports Conference 1999* (Perth, Australia), vol. 2, pp. 438-443.

Mead, S.T. and Black, K.P., 2001a. Predicting the breaking intensity of surfing waves. *In:* Black, K.P. (ed.) *Natural and artificial reefs for surfing and coastal protection. Journal of Coastal Research*, Special Issue No. 29, pp. 51-65.

Mead, S.T. and Black, K.P., 2001b. Field studies leading to the bathymetric classification of world-class surfing breaks. *In:* Black, K.P. (ed.) *Natural and Artificial Reefs for Surfing and Coastal Protection, Journal of Coastal Research*, Special Issue No. 29, pp. 51-65.

Mead, S.T.; Atkin, E.A., and Phillips, D.J, 2011. *Sediment transport investigations of a West Coast beach - Repeated bathymetry and beach surveys of Maori Bay for morphological modelling and calibration.* Raglan, New Zealand: eCoast Marine Consulting and Research.

Mead S.T. and Borrero, J.C., 2017. *Chapter 16 -Surf science and multi-purpose reefs. In:* Green, D.R., Payne, J.L. (eds.), *Marine and Coastal Resource Management: Principles and Practice*. London, United Kingdom: Routledge, 328p.

Mead, S.T.; Scarfe, B.; Blenkinsopp, C., and Black, K., 2004. *Feasibility and preliminary design study for an artificial surfing reef at Mahomet's Beach, Geraldton, Western Australia.* Geraldton, Western Australia: Geraldton

Boardriders Club, *Technical Report.*

Moores, A., 2001. Using video images to quantify wave sections and surfer parameters. Hamilton, New Zealand: The University of Waikato, Master's thesis, 143 p.

Morse and Brunskill, 2004. *Wavetrack: New Zealand surfing guide*. Mount Maunganiu, New Zealand: Greenroom Surf Media, 549p.

Murphy, M. and Bernal, M., 2008. *The Impact of Surfing on the Local Economy for Mundaka, Spain*. Madrid, Spain: Autonoma University, 31p.

Orchard, S.; Atkin, E.A., and Mead, S.T., 2019. Development of the regional significance concept for surf break management in New Zealand. *In:* Bryan, K.R. and Atkin, E.A. (eds.), *Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research*, Special Issue No. 87, pp. 23–34.

Peregrine, D.H., 1983. Breaking waves on beaches. *Annual Reviews of Fluid Mechanics*, 15, 149-178.

Peregrine, D.H. and Jonsson, I.G., 1983. *Interaction of waves and currents*. Fort Belvoir, U.S.: USACE miscellaneous report No. 83-6, 94p.

Peryman, P.B. and Orchard, S., 2013. Understanding the values and management needs of New Zealand surf breaks. *Lincoln Planning Review*, *4*(2).

Phillips, D.J., 2004. Sediment dynamics of a shallow exposed surfing headland. Hamilton, New Zealand: University of Waikato, Ph.D. thesis, 269p.

Phillips, D.J. and Mead, S.T., 2008. Investigation of a large offshore sandbar at Raglan, New Zealand: Impacts on surfing amenity. *Shore and Beach*, 76(2).

Pratte, T.P.; Walker, J.R.; Gadd, P.E., and Leidersdorf, C.B., 1989. A new wave on the horizon: towards building surfing reefs nearshore. *In: Proceedings for Coastal Zone 1989,* pp. 3403–3411.

Rainger, T., 2011. *The New Zealand good beach guide: North Island.* Raglan, New Zealand: Clean Media Ltd., 243p.

Rosier, J., 2004. *Independent review of the New Zealand Coastal Policy Statement.* Palmerston North, New Zealand: School of People, Environment and Planning, Massey University, 135p.

Rosier, J., 2005. Towards better national policy statements: NZCPS review. *Planning Quarterly, March 2005*: 26-28.

Sayce, A., 1997. Transformation of surfing waves over steep and complex reefs. Hamilton, New Zealand: The University of Waikato, Master's thesis (unpublished).

Scarfe, B.E., 2002. Categorising surfing manoeuvres using wave and reef characteristics. Hamilton, New Zealand: The University of Waikato, Master's thesis, 181p.

Scarfe, B.E.; Healy, T., and Rennie, H.G., 2009a. Research-based surfing literature for coastal management and the science of surfing—A Review. *Journal of Coastal Research,* 25(3), 537-559.

Scarfe, B.E.; Healy, T., and Rennie, H.G., 2009b. Sustainable management of surfing breaks. *Journal of Coastal Research,* 25(3), 684-703.

Schrope, M., 2006. Oceanography: creating the perfect wave. *Nature*, 444(7122), 997–999.

Sport and Recreation New Zealand, 2008. *Sport, recreation and physical activity participation among New Zealand adults: Key results of the 2007/08 active NZ survey*. Wellington, New Zealand: SPARC, 24p.

Walker, J. R. and Palmer, R.Q., 1971. *A general surf site concept*. Hawaii, U.S.: LOOK Laboratory TR-18, University of Hawaii, Department of Ocean Engineering.

Walker, J.R.; Palmer, R.Q., and Kukea J.K., 1972. Recreational surfing on Hawaiian reefs. *Proceedings of 13th Coastal Engineering Conference, 1972,* pp. 2609-2628.

Walker, J.R., 1974a. *Recreational surf parameters*. Hawaii, U.S.: LOOK Laboratory TR-30, University of Hawaii, Department of Ocean Engineering.

Walker, J.R., 1974b. *Wave transformations over a sloping bottom and over a three-dimensional shoal*. Hawaii, U.S.: University of Hawaii, Ph.D. dissertation.

Walker, J.R., 1997. A summary of surfing reef parameters*. First International Surfing Reef Symposium* (Sydney, Australia).

Young, D., 2003. *Monitoring the effectiveness of the New Zealand coastal policy statement: Views of local government staff.* New Zealand, Wellington: Department of Conservation, 53p.

Appendix D. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance: Initial Characterisation of Study Sites

SURF BREAK RESEARCH

Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance: Initial Characterisation of Study Sites

Report prepared as part of a Ministry of Business, Innovation and Employment project:

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

WWW.SURFBREAKRESEARCH.ORG

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

eCoast
eTakutai

HCL
Hume Consulting Ltd

MAORI HEALTH & DEVELOPMENT

Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance: Initial Characterisation of Study Sites

Reviewed by

Dr Dave Phillips (Assoc. Prof.) Unitec, New Zealand.

Date: 11 December 2016

CPENG FIPENZ IntPE

IPENZ No. 228069

Approved for Release

E. Atkin (Director), eCoast

1 February 2017

Authors

Ed Atkin, eCoast Marine Consulting and Research

Terry Hume, Hume Consulting Ltd

Karin R Bryan, University of Waikato

Shaw Mead, eCoast Marine Consulting and Research

Jordan Waiti, Māori Health & Development

Executive Summary

This report is the first in a series of reports detailing the progress of the Ministry for Business, Innovation and Employment-funded project on developing guidelines and methodology for protecting surf breaks of national and regional significance. The first year of the project was to take stock of existing knowledge at representative sites around New Zealand, using information from local stakeholder meetings (including hui and korero with open and inclusive discussions), stakeholder surveys, literature review and websites.

This report summarises the state of knowledge around the 7 surf breaks that form the basis of this project and provides an overview of the procedures that were used to collect this information. Consistent themes are that the breaks lack baseline monitoring data from which to base a quantitative understanding of the factors that control the quality of breaks. Considerable qualitative data has been collected from the open korero and feedback at the stakeholder meetings/hui, surveys, and web material, along with evidence prepared for various previous court hearings surrounding the breaks. Key perceived and/or potential anthropogenic threats for stakeholders are development (e.g. the marina at Whangamata, the Port of Otago dredge spoil disposal, the Manu Bay boat ramp, the Airport at Lyall Bay), water quality and increased surfer numbers. Natural threats were particularly evident on the sandy sites such as Piha, Aramoana and Wainui, where morphological changes affect the quality of the break from time to time. Differentiating the natural effects from the anthropogenic effects was a common theme. The existence and quality of the surf breaks being investigated formed an essential part of the local culture, both for Māori and non-Māori and for the visitor and tourist experience, and re-enforces the vital essence of the importance of this body of research work to New Zealand and its people.

Contents

Figures

Tables

1 Introduction

The objective of this project is to build a knowledge base and to develop management guidelines for New Zealand's nationally and regionally significant surf breaks. Policy 16 of the New Zealand Coastal Policy Statement 2010 (NZCPS; Department of Conservation, 2010) provides a legislative framework that identifies and calls for the protection of surf breaks of national and regional significance by "ensuring that activities in the coastal environment do not adversely affect the surf breaks" and by "avoiding adverse effects of other activities on access to, and use and enjoyment of the surf breaks". While this breaks new ground as the world's first environmental policy to specifically identify surf breaks as protected spaces, it lacks effectiveness because there are no clear, quantitative measures or guidelines describing the oceanographic or geomorphic characteristics of the coastal zone that contribute to the functionality of a surf break.

This research will provide information and understanding of surf breaks leading to guidelines to enable informed decision-making by council staff, engineers and consultants about activities in coastal areas that have the potential to threaten the functionality of New Zealand's surf breaks. Seven surf breaks were selected for detailed study within this project. These were selected to encompass the range of different types of surf breaks and the variety of threats to surf breaks within New Zealand. Data collection will be primarily through the use of remote camera stations. Images are captured 7 days a week, 365 days a year, along with automated systems to process the data and extract important physical parameters such as breaking wave patterns and the formation of rip currents. This will be supported by bathymetric surveys of the seabed, numerical modelling and data such as a surfer's position and speed as they ride waves.

As a first stage of the research, 6 stakeholder meetings were conducted to collect data and local knowledge relating to cultural, geomorphic and historical background at each of the sites. This report summarises the findings of this stage[1].

The Principal Investigators for this project are the University of Waikato's Associate Professor Karin Bryan; Mr Edward Atkin and Dr Shaw Mead of eCoast Marine Consulting and Research; Dr Terry Hume of Hume Consulting Ltd, former Principal Scientist and National Projects Manager of the National Institute of Water and Atmospheric Research; and Dr Jordan Waiti,

[1] It should be noted that this document reports the findings and opinions of stakeholders, and the information contained in this document is not the opinion and/or views of the authors or their associated institutions, unless otherwise stated.

an expert in Māori Public Health, Māori Exercise Psychology, and Māori community engagement.

A project steering committee, containing representation from the Department of Conservation, Landcare Research, Surfbreak Protection Society, Surf Life Saving New Zealand, Waikato Regional Council, Auckland Council, and Lincoln University, ensure the project achieves its goals, and that relevant the stakeholders are involved and the outcomes are inclusive of their views and local knowledge.

2 Surf Science Overview

The NZCPS defines a surf break as *a natural feature that is comprised of swell, currents, water levels, seabed morphology, and wind. The hydrodynamic character of the ocean (swell, currents and water levels) combines with seabed morphology and winds to give rise to a "surfable wave". A surf break includes the "swell corridor" through which the swell travels, and the morphology of the seabed of that wave corridor, through to the point where waves created by the swell dissipate and become non-surfable.*

"Swell corridor" means the region offshore of a surf break where ocean swell travels and transforms to a "surfable wave".

"Surfable wave" means a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the wave crest.

Surfing waves are defined objectively by a body of engineering literature that includes the quantification of breaking wave characteristics. Waves for high-performance surfing are attractive to surfers because they have steep, plunging faces, and are often "hollow", providing the speed and correct shape surface necessary to undertake advanced manoeuvres. Surfers, particularly beginners, also benefit from less steep, spilling waves.

The vortex ratio of a breaking wave describes the shape of a plunging breaker by evaluating the length and width of the wave's vortex (Mead and Black, 2001c). The vortex ratio provides a more detailed evaluation of breaking wave shape than the traditional Irribarren number (Irribarren and Nogales, 1949; Galvin, 1968; Battjes, 1974), which does not account for variable seabed gradients and does not relate to surfing wave quality or breaking intensity (Mead and Black, 2001c). Vortex ratio accounts for the subtle differences within the plunging breaker category and describes the actual shape of the wave based on the local bathymetry, which is imperative for describing surfing wave quality (Mead and Black, 2001c).

Waves close to the spilling range of the plunging wave spectrum have high vortex ratios as the width of the wave vortex is very small compared to the length. At the other end of the spectrum, toward collapsing waves, vortex ratios are lower as the vortex width is large relative to the length. Mead and Black (2001c) created a classification scheme of breaking intensity using the vortex ratio from actual surf breaks and included descriptive terms. High vortex ratios were given a breaking intensity classification of medium and are considered much more easily surfed than waves with the lowest vortex ratios in the study, which were given a breaking intensity classification of extreme.

Surfers also require waves that peel, that is, those that break laterally along the wave crest. A wave that breaks along the length of its crest simultaneously is termed a “close out”. After the wave has broken, these waves can be used by beginner surfers learning to stand up. However, for the most part, surfers require waves that break along their length at a rate slow enough to allow the surfer to progress along the wave face.

Fundamentally related to both bathymetric configuration and surfing wave quality is a breaking wave’s peel angle (Walker 1974a, b; Hutt et al., 2001). This is defined as the angle between the path of the wave break point and the crest of the unbroken wave. The peel angle is directly related to the speed at which the breaking part of the wave laterally translates across the wave face.

The lower the peel angle, the faster the rate of breaking. A peel angle of zero indicates a close-out. A peel angle of 90° indicates that the wave has broken but does not translate laterally. Walker (1974b) and later Hutt et al (2001) related peel angle, along with wave breaking height, to a surfer’s skill; Table 2.1 present the work of Hutt et al (2001), as skill level increases, peel angle decreases.

Table 2.1: Rating of the skill level of surfers (Hutt *et al.,* 2001)

Rating	Description of Rating	Peel Angle Limit (°)	Min/Max Wav Height (m)
1	Beginner surfers not yet able to ride the face of a wave and simply moves forward as the wave advances	90	0.70/1.00
2	Learner surfers able to successfully ride laterally along the crest of a wave	70	0.70/1.01
3	Surfers that have developed the skill to generate speed by 'pumping' on the face of the wave	60	0.70/1.02
4	Surfers beginning to initiate and execute standard surfing manoeuvres on occasion	55	0.70/1.03
5	Surfers able to execute standard manoeuvres consecutively on a single wave	50	0.70/1.04
6	Surfers able to execute standard manoeuvres consecutively. Executes advanced manoeuvres on occasion	40	0.70/1.05
7	Top amateur surfers able to consecutively execute advanced manoeuvres	29	0.70/1.06
8	Professional surfers able to consecutively execute advanced manoeuvres	27	0.70/1.07
9	Top (44[2]) professional surfers able to consecutively execute advanced manoeuvres	Not Reached	0.70/1.08
10	Surfers in the future	Not Reached	0.70/1.09

[2] As per 2001 – current top professional circuit consists of 34.

Surf breaks can be classified with reference to their seabed substrate and morphology; the seabed morphology is the over-riding factor that influences the surfing quality parameters of breaking intensity and peel angle. Mead (2000) provides the following descriptions of these classifications:

- **Point break** – surf break where the waves break down a headland feature, which may have a sand, gravel or rock seabed.
- **River and estuarine deltas** – surf breaks on sand and/or gravel deposits forming bars/deltas at the mouths of rivers, inlets and estuaries.
- **Rock ledges** – very sharp/steep rocky reefs where the waves break along the steep edge of the ledge.
- **Rock reefs** – solid rock or boulder reef substrate, which may or may not extend shoreward to the beach/coast.
- **Sand beaches** – also known as beach breaks, surf breaks on nearshore bars at sandy beaches.

A surf break may be composed of a combination of surf break types and/or substrates. For example, a point break can be largely made up of boulders and rock, but the surfing wave quality can be dependent, to varying degrees, on the movement of sandy material.

Rocky reefs, point breaks and ledges, and in some cases, river and estuarine deltas, provide very consistent platforms for surfing. The mobile nature of sand beaches, and in some cases, river and estuarine deltas, means that these surf breaks have the potential to be very fickle in providing good surfing conditions. Surfers often refer to beach breaks as having good or bad banks, this concerns the formation of certain morphological features that can be transient in both space and time.

3 Study Sites

A decision-making matrix was used to select the seven surf break sites for study in this project (Appendix B). The Nationally Significant Surf Breaks of Aramoana and Whareakeake in Otago met certain criteria and hosted remote sensing systems prior to the start of this project. In choosing the other sites the 17 nationally significant surf breaks and 5 other regionally significant surf breaks of public interest (Lyall Bay, Piha, Matakana Island, Main Beach Tauranga, and Fitzroy) were evaluated using the matrix. The scoring categories of the matrix were: access, infrastructure, environment sensitivity, threats, usage, dependent population, SLSNZ presence, and effectiveness of remote monitoring methods. The 6 highest scoring surf breaks in the matrix, from highest to lowest, were Whangamata Bar, Manu Bay, Lyall Bay, Whale Bay, Piha and Wainui Beach. With the interest of ensuring that the chosen sites were representative of surf breaks across New Zealand, and collating as much useful data within budgetary constraints, Whale Bay was excluded from the study, the reason being that Manu Bay and Whale Bay are both similar exposed west coast boulder/rock point breaks within 1 km of each other. The locations of the seven selected sites are shown in Figure 3.1.

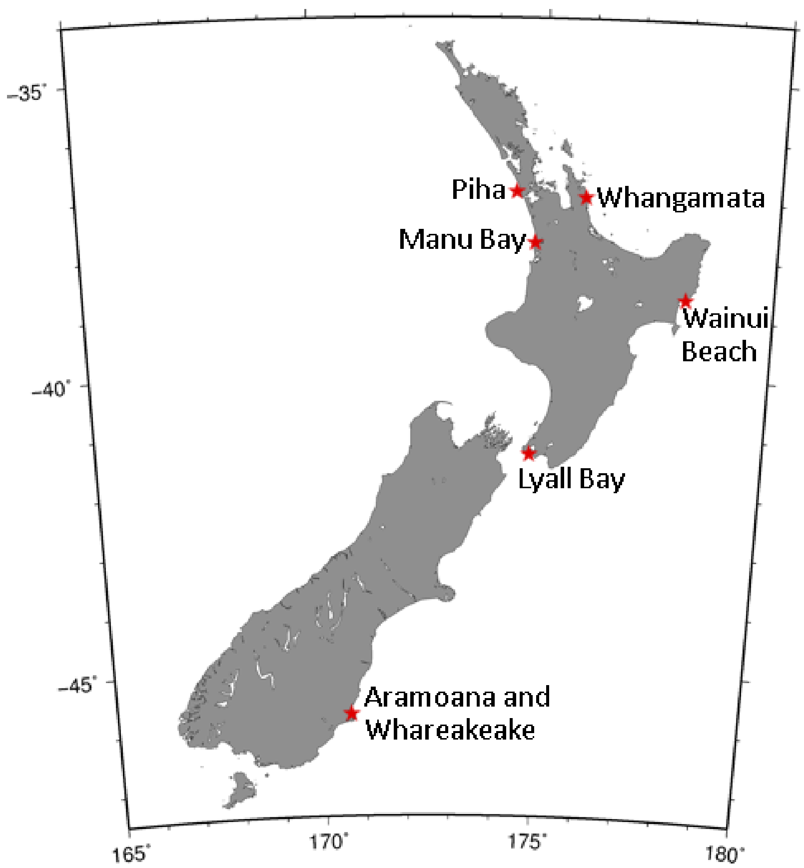


Figure 3.1: Map of New Zealand showing the location of the seven study sites.

4 Stakeholder Engagement

4.1 Iwi Engagement

Paramount to the success of this project was proper and meaningful engagement and consultation with tangata whenua (local Māori, people of the land). A first step to establishing each new site and to determining the value of each site for surfing was to approach the tangata whenua or local Iwi who have kaitiakitanga (guardianship) of each area. The purpose of the Iwi engagement process was two-fold. Firstly, utmost importance was placed on engaging with Iwi early in the research process to seek approval for conducting research within their rohe (tribal boundaries), and ensure that the research aims and methods aligned with the local Iwi's values and beliefs. This process acknowledges the relationship between the Crown and Māori, as per the Treaty of Waitangi and Policy 2 of the New Zealand Coastal Policy Statement 2010 (Department of Conservation, 2010).

Secondly, the Iwi engagement process through 'kanohi-ki-te-kanohi' (face to face) hui and korero sought to determine how each surf break is valued by Iwi, how the surf break influences areas which are of significance to local Iwi, and to identify local Iwi preferences with respect to monitoring and protecting the local surf break. In addition, traditional knowledge of the surrounding area was also investigated to highlight the special relationship between the local area and local Iwi. Table 4.1 outlines the Iwi representatives who were sought for comment and approval for each respective site. All Iwi representatives were supportive of the project.

4.2 Stakeholder Workshops

Stakeholder meetings were held at Lyall Bay (12/3/2016), Piha (2/4/2016), Gisborne (23/4/2016), Dunedin (14/5/2016) and Whangamata (28/5/2016) and Manu Bay (25/06/2016). These were run for 2 hours, from 2 to 4 pm on a Saturday afternoon (depending on venue availability).

The meetings were advertised via the project website, through social media (Facebook) and via articles in the local press and local Boardriders associations. Prior to the meeting, local iwi groups were contacted and visited to gauge their interest, get their views and local knowledge, as well as any concerns that they may have in relation to the project.

The most difficult part of the meetings was setting the tone so that all participants felt welcome and included, and able to contribute effectively. The processes evolved substantially during the workshops (mainly in response to feedback from Dr Jordan Waiti). Dr Waiti opened these stakeholder workshops with a mihimihi (formal greeting) in te reo Māori.

Table 4.1: Iwi representatives during stakeholder consultation.

Name of Representative	Iwi Affiliation	Surf Break	Date (2016)	Supportive of Project
Wayne Knox	Te Kawerau a Maki	Piha	1st April	Yes
Te Warena Taua	Te Kawerau a Maki	Piha	1st April	Yes
Lee August	Ngāti Awa, Te Ātiawa	Lyall Bay	3rd March	Yes
Matiu Rei	Ngāti Toa Rangatira	Lyall Bay	8th March	Yes
Morrie Love	Ngāti Awa, Te Ātiawa	Lyall Bay	11th March	Yes
Mike Baker	Ngāti Whanaunga, Ngāti Haako	Whangamata	26th May	Yes
Brendan Flack	Kati Huirapa, Kai Tahu	Aramoana/Whareakeake	13th May	Yes
Natalie Karaitiana	Kai Tahu	Aramoana/Whareakeake	13th May	Yes
Angeline Greensill	Tainui Awhiro	Manu Bay	15th September	Yes
Daniel Kereopa	Tainui Awhiro	Manu Bay	15th September	Yes
Malibu Hamilton	Tainui Awhiro	Manu Bay	15th September	Yes
Sandy Hounuku	Tainui Awhiro, Ngaati Hounuku	Manu Bay	15th September	Yes
Nick Tupara	Ngāti Oneone	Wainui	21st April	Yes
Nicky Searancke	Ngāti Oneone, Ngāti Rakaiatane	Wainui	23rd April	Yes

The mihimihi process involved acknowledging the hau kainga (local tribe/s) and their presence as the ahi kaa (keeping the home fires burning). Dr Waiti would mention local landmarks of significance (e.g., rivers, lakes, mountains, islands) and acknowledge the tipuna (eponynous ancestor) from whom the hau kainga descend from. Acknowledging local landmarks of significance emphasised the importance of the enviroment to Māori. It also reaffirmed the essence of the project, that is, the correct management of a natural feature.

To conclude the mihimihi process Dr Waiti spoke about his own whakapapa (genealogy) and upbringing. This was to let the hau kainga know about Dr Waiti's tribal affiliations and background, so that whakapapa links could be established and/or reaffirmed. The rest of the research team introduced themselves, provided their background and involvement in the project.

Prior to these stakeholder workshops, Dr Waiti met with local Iwi representatives 'kanohi ki te kanohi'. Some Iwi representatives made special mention of the value of these prior engagements as separate from the stakeholder workshops, and acknowledged the research team for doing so.

After the introduction, the stakeholder workshops operated in 3 stages. The first stage was largely based around 3 to 4 "stations" where large aerial photographs of the relevant study site were spread out on tables and available for annotation during smaller group discussions (Figure 4.1). Secondly, a presentation by the study team summarised the projects aims and methodology. Following this, an open floor discussion with questions and answers took place.

During each stakeholder meeting 3 appropriate local surfers were identified and allocated with a Rip Curl Search GPS Watch. The watch records data such as surfer position and speed while surfing. The data will be used in later stages of the study. The stakeholder meetings were also used to identify suitable host sites for camera locations to permanently monitor the surf breaks.

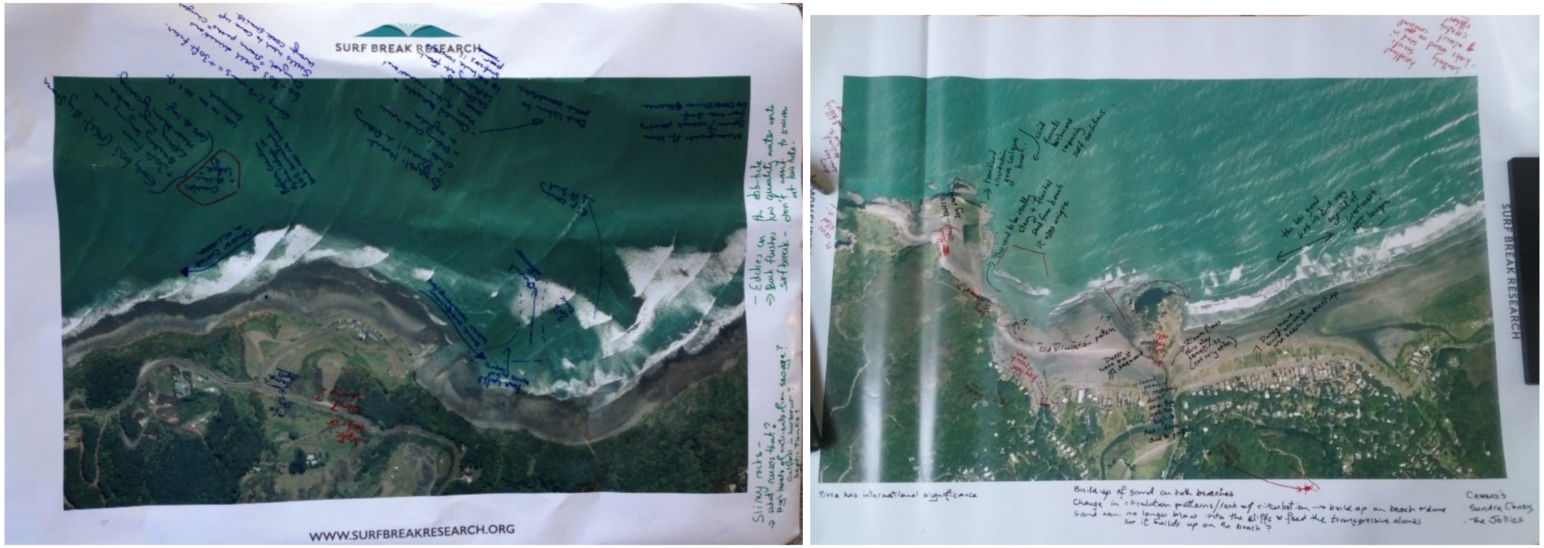


Figure 4.1. Examples of posters annotated with information by stakeholders for Manu Bay (left) and Piha (right).

Figure 4.2. Stakeholder meetings at Piha, with a participant filling out the survey (left) and at the Boardriders club in Dunedin (right)

5 Aramoana

Aramoana is a located some 20 km north east of Dunedin in Otago, South Island. The beach at Aramoana is named Spit Beach, but known colloquially as "The Spit", and is a Nationally Significant Surf Break (Department of Conservation, 2010) (Figure 5.1).

Figure 5.1. Aramoana Beach (left of the mole) at the entrance to Dunedin Harbour (Source, Land Information New Zealand, ortho-photo archive).

5.1 Environmental Setting

Spit Beach is situated on the north side of the entrance to Otago Harbour. The sandy beach's extents are demarked to the southeast by a ~1.25 km long breakwater – "The Mole", and to the northwest, towards Heyward Point, by cliffs composed of Dunedin volcanic complex. The beach faces northeast and is ~1.8 km long and in the central part of the beach, remnant rock stacks are exposed.

The environment around Aramoana has been greatly modified, with the construction of the Mole put in place to help maintain the Port's entrance from infilling. The Mole is constructed in part by a series of shipwrecks. In addition, there is a designated clean dredge spoil disposal site just offshore of the beach. The spoil ground has been used since the 1980s for the disposal of clean spoil from the Otago Harbour entrance, which has been removed to maintain a navigable channel. In recent times, the Port Company has had consent to dispose of 200,000 m^3 of material per annum; however, the dredging disposal site has not been used to its full capacity.

Further offshore from Spit Beach is a large ebb tidal delta extending roughly north from Tairoa Head. The offshore end of the delta shoals to ~7.5 m below CD (LINZ Chart NZ6612). The terminal lobe of the delta is located northeast of Spit Beach. Considering just the tip of the delta, the feature is 975 m wide (shore parallel relative to Spit Beach) and 760 m long (shore normal). The inshore toe of the feature is 2,250 m from the shoreline. The delta head is rounded at the northern end and is best described as semi-elliptical (Mead et al., 2011).

The bathymetry offshore at Aramoana is complex; incident waves pass over a rapid succession of abrupt depth changes which serve to focus the incoming waves. Immediately in the lee of the ebb tidal delta lies a deep channel and inshore of this is the spoil ground. Despite this, the beach plan shape does not show evidence of a salient (which would normally form in the lee of shallow offshore features), which may be due to the constricted length of the beach (a rock headland to the west and "The Mole" to the east), and because the natural processes and offshore bathymetry are modified by nearshore dumping of clean spoil material (Mead et al., 2011).

Single (2015) considers the northern end of the beach at Aramoana relatively stable, subject to episodes of erosion and accretion which occur as a response to changes in the wave environment. The beach and dune scape here is narrow, and backed by the steep Dunedin volcanic complex cliffs. At the southern end of the beach, Single (2015) observed rapid changes, associated with the construction of "The Mole", and periods of both erosion and accretion.

5.2 Social and Cultural Aspects

5.2.1 Local Māori History and Traditional Use

The name Aramoana translates to "pathway of the sea". Te Rūnaka o Otākou holds manawhenua (territorial rights) over Aramoana, but share this responsibility with nearby hapū such as Kāti Huirapa and the wider Kai Tahu iwi. Aramoana forms the northern shore of the Otago Harbour, and was once a small village right up until the 1900's (Potiki, 2011).

On the southern shore of the harbour was the much more populated Otākou settlement, which now bears the marae of Otākou. Various events of significance occurred at Otākou, and knowadays, Otākou marae stands as a centrepiece for the tangata whenua (local Māori, people of the land) of this region.

Otago Harbour is a singular site of importance for Otākou Māori, and for the wider Kai Tahu peoples. It has been an important food source, a major highway, a sheltering location for human settlement, a place of burial, and a symbol of the ancestral, spiritual, and religious practices of the Kai Tahu people (Potiki, 2011).

Aramoana, like the other nearby coastal bays, was an important mahika kai area (food source) for local Māori. Between Aramoana and Waitati, elders in 1880 counted 41 mahika kai sites. The various foods included fern root, tui, pigeons, tuna, paua, grouper, seals, flounder, mullet, pipi, cockles, and flax (Potiki, 2011).

Kāi Tahu ki Otago Ltd (KTKO) is the local organisation who focus on the environmental health of the area. Representing the surrounding rūnaka of Otago - Te Rūnanga o Moeraki, Kāti Huirapa Rūnaka ki Puketeraki, Te Rūnanga o Ōtākou and Hokonui Rūnanga, KTKO Ltd are working closely alongside Port Otago in regards to the port dredging, with Rūnaka members on each of the port dredging boards. The Rūnaka are supportive of the dredging, subject to various conditions, such as improving the monitoring (N. Karaitiana, personal communication, 13th May 2016). The Rūnaka see the benefits as economical and employment opportunities for their people (N. Karaitiana, personal communication, 13th May 2016).

5.2.2 Surfing and Surf Life Saving History

Surfing in Dunedin has a long history, with the Southcoast Boardriders being established in 1966. In addition, the famous surfer, Duke Kahanamoku, visited St Clair Beach during his 1915 tour of New Zealand. The Dunedin area is also home to Elliot Brown, the 2016 under-18s National Champion and a Junior World Championship competitor. Dunedin was host to the 2016 National surfing championships.

The history of surfing at Aramoana and Whareakake (see Section 11) is not well documented. Being located some ~20 km as the crow flies from Dunedin, surfing at Aramoana caught on much later than at St Clair and St Kilda, but by the mid-1970s there were surfers frequenting Aramoana (R, Rust. personal communication, 2016). Today Aramoana Beach is popular for surfing and swimming but can be hazardous to water users as it can receive large swell. Rip currents and inshore holes can also form anywhere along the beach. Inexperienced water users are at high risk of being overcome by large waves, stepping or being washed into inshore holes and channels, and being swept out to sea by rip currents. There is no surf lifeguarding service at the site and there are no surf rescues recorded at Aramoana[3] (Surf Life Saving New Zealand, 2016).

5.3 Surf Break Characteristics

Aramoana is a sand bottom beach break, and is known for its hollow and powerful waves produced from “wedging peaks”. It is more popular than Whareakake, and surfing is viewed as an important part of the community in the village of Aramoana (McKenzie, 2014). Aramoana receives swell ranging from the north, through east, to the south, with swell from the north and east providing what is considered optimum incident wave conditions for surfing. There are different “peaks” for surfing along Spit Beach. At the far eastern end, against The Mole, is “Kiddies Corner”. During the stakeholder meeting, the consensus amongst local surfers was one that the surfing wave quality has recently (2016) improved in this area, and the same was reported for the surfing area ~500 m north of “The Mole”, approximately halfway to Keyhole (Bear) Rock. The premier surfing is located between Keyhole Rock and the next set of substantial rocky outcroppings toward the north. The beach break further northward is considered to be better during more southerly swell. This is roughly consistent with the Port of Otago survey of surfers that indicate middle and north Aramoana beach had the best surf (McKenzie, 2014). Also, Aramoana was shown to have better surfing conditions at low tide, and also during offshore winds (McKenzie, 2014).

Kilpatrick (2005) and Scarfe *et al.,* (2009b) have both shown that there are no outstanding bathymetric features in the nearshore zone at Aramoana that would produce breaking waves conducive to surfing. With little to no discontinuities in the direction of isobaths in the nearshore, pre-conditioning of waves is required to set up wave focussing, alongshore wave height gradients, wave-wave interactions and/or bifurcation (splitting) of wave crests.

[3] Note that the above data only include rescues that were performed by surf lifeguards where an incident report form was completed and entered into the Patrols and Memberships database. As such, there are likely to be a number of other rescues that were performed by other members of the public, or by surf lifeguards where an incident report form was not completed.

The pre-conditioning of waves prior to breaking at Aramoana is two phase. Firstly, incident waves focus on the terminal lobe of the ebb tidal delta creating a localised band of increased wave heights, realigning wave crests and setting up a longshore wave height gradient. The band of increased wave height is generally focused central to Spit Beach. Following this, the mound of the nearshore dump ground acts to do the same but to a much lesser degree.

While a number of reports, statements of evidence and affidavits have been produced concerned with the management of Aramoana and other local surf breaks regarding the ongoing dredge disposal (McKenzie *et al*., 2014a, 2014b), no single study has produced field or modelled data reporting either vortex ratio (breaking intensity) or peel angle values.

Figure 5.2 presents approximations of peel angles annotated on a Google Earth image from June 2015. The peel angles range from 35° to 69°, showing a range of conditions for skilled (low angles and fast peeling waves) to less skilled (higher angles and slow peeling waves) surfers. The incident sea state conditions at the time the image was captured may have involved multiple swells, however, the bifurcations of wave crests and “peaky” surfing wave formations (focusing), for which Aramoana is well known for, are clearly evident. Figure 5.3 shows this peaky character, with a longshore wave height gradient – wave heights dramatically reducing from the initial point of breaking.

Figure 5.2. Wave peel angles at Aramoana annotated on Google Earth imagery.

Moorse and Brunskill (2004), describe Aramoana in the New Zealand Surf Guide as one of New Zealand's finest beach breaks—with hard-breaking peaks producing very hollow barrels. This description indicates a wave that would fall into the high-breaking intensity classification of Mead and Black (2001c).

Figure 5.3. Aramoana peaks showing clear longshore wave height gradient. Image courtesy of Rambo Estrada.

5.4 Current and Potential Threats

The primary threat to the surf break at Aramoana is Otago Harbour dredging activity and subsequent disposal of material in the Aramoana spoil ground. As noted above, the high-quality surfing conditions at Aramoana are mostly due to refraction/focussing over the ebb-tidal delta. However, it is also important to note that Aramoana has been modified by human activities ("The Mole", the channel entrance and dredge disposal), and as such will require ongoing management. Sediment transport is from east to west, and with the development of the Port entrance channel, this material is trapped within the entrance and requires dredging and placement to the west (i.e. Aramoana) to ensure that the coast west of the entrance does not experience a deficit of sand, which can lead to coastal erosion.

Nearshore disposal in the Aramoana dump site began in the early 1980s, at which time some of the best surfing conditions were experienced (R, Rust, personal communication, 2015).

However, by the early years of the 21st century, there was a general concern that Aramoana was no longer providing the high-quality surfing waves that it had in the past.

Continual addition of sand to the nearshore disposal site not only impacted local processes of wave refraction and breaking, but anecdotal evidence also suggested that the embayment had become over-full with sand, which had the negative impacts of breaking waves offshore at the dumpsite and closing waves out without peeling (i.e. not conducive to good surfing conditions) because the sand from the dumpsite had formed a large shallow platform in the nearshore.

Concern was raised when the renewal of this disposal ground coincided with plans to deepen the access channel, with a proposal to greatly increase the volume of sand to be dumped at the Aramoana disposal site (POL, 2010). While there were already concerns with the potential that the Aramoana disposal site was already 'too full' of sand, increased volumes of disposal may have resulted in further detrimental changes to this nationally significant surfing break due to both the deepening of the channel and the rapid shoaling at the spoil ground (i.e. greatly increased volumes of spoil disposal in this area; Mead et al., 2011).

The Surfbreak Protection Society (SPS) and South Coast Boardriders opposed the proposal, and a settlement was agreed upon outside of Court to obtain a 3-year temporary permit with greatly reduced disposal at the nearshore site. No dredge material was placed at Aramoana for the first 2 years, during which time it was perceived by all parties involved that surfing conditions had improved.

The Port of Otago has recently applied for a 35-year resource consent to dispose of dredge material at Aramoana (since sand is required to ensure the health of the beach system), which includes ongoing trials and continued monitoring to ensure that the break is well-managed and continues to be one of New Zealand's Nationally Significant Surfing Breaks. This continued monitoring is being undertaken using remote video camera installations.

5.5 Summary

In summary, the surf break at Aramoana is of significant cultural and social value to the region. The break is largely controlled by the way in which waves are preconditioned by offshore bathymetry (the ebb tidal delta and the nearshore dredge spoil disposal site).

6 Lyall Bay

Lyall Bay is adjacent to Wellington Airport (Figure 6.1). It is the country's most historic surfing venue with the Hawaiian Duke Kahanamoku (The Duke), a 5-time Olympic swimming medallist, introducing surfing to New Zealand in 1915. Lyall Bay is culturally and regionally significant to the sport of surfing in New Zealand. Stakeholders in Lyall Bay recognise that the surf break provides a valuable resource for economic, social and recreational growth; that surf breaks of real quality are rare; and note that access to this inner-city break makes it unique.

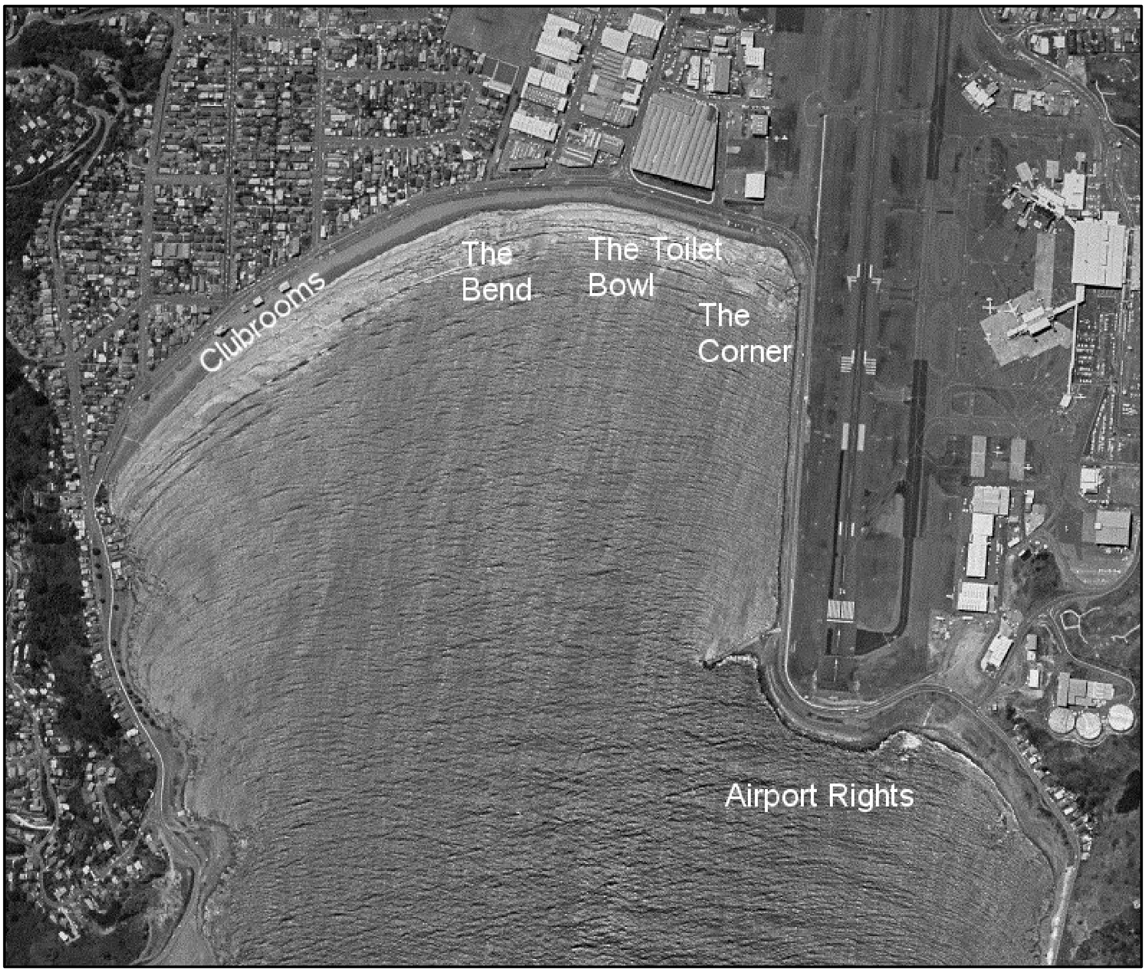


Figure 6.1. Lyall Bay. (Source Land Information New Zealand Orthophoto archive 2012-13).

6.1 Environmental Setting

Lyall Bay is a crescent-shaped beach, approximately 1.4 km long, and situated between a rocky headland to the west, and Wellington International Airport breakwater to the east. The beach is backed by a mix of low dunes and a seawall, behind which there is substantial development including car parks, a coastal reserve, residential properties, and retail and industrial businesses. The beach is largely cut off from the external sediment supply by the large headlands so the sediment budget in the bay is relatively stable (Pickrill, 1979). It is composed of medium-grained sediment, interspersed with larger gravel and cobbles sourced from eroded rocky outcrops, shore platforms, and coastal protection structures. It typically adopts a rhythmic bar and beach morphology, which is one of the higher energy forms of the intermediate beach states, as described by Wright and Short (1984). However, the western end of the beach more often adopts a low tide terrace morphology, due to lower wave energy in this area. The beach is oriented due south and the flanking headlands extend offshore as submerged reefs.

From a historical perspective, the sandy beach is formed along the southern edge of the tombolo that connects the Miramar Peninsula in the east to mainland North Island in the west. The tombolo is built across what was formerly another entrance to Wellington Harbour (Carter and Lewis, 1995).

Lyall Bay is a highly-modified beach environment. Where there used to be an established dune field is now residential and commercial buildings and infrastructure, however, the council is currently undertaking a restoration project of the dunes (Mead and Phillips, 2016); the bay is semi-enclosed by walls, roads and parking; stormwater discharges into the bay from over 20 different outfalls; the eastern third of the bay was reclaimed for the airport.

The airport reclamation resulted in a change in the plan shape of the bay, with a deepening in the centre. The main driver of beach change in Lyall Bay is wave-energy. The engineered flanks of Lyall Bay result in wave energy loss through refraction toward the shallower sides of the Bay. This results in smaller wave heights at the beach than at the entrance to the bay, as well as a wave height gradient with the greatest wave heights in the middle of the bay, decreasing towards the sides. One of the effects of this is the sorting of sand and gravel, from coarsest to finest from centre to the ends of the beach respectively. (Pickrill, 1979).

There is very little alongshore sediment transport. Yet, strong bi-modal winds at Lyall Bay have a large impact on the beach. Northerly winds often lead to accretion at Lyall Bay, with the combination of long-period waves and offshore winds (which blow the surface water offshore, bringing the bottom water shoreward), transporting sand shoreward. It is noted that there is only a very small supply of ‘new’ sand that can be transported into Lyall Bay (Carter and Lewis, 1995). The southerly onshore winds cause erosion of the beach, especially when they are strong (i.e. storm conditions) (Mead and Phillips, 2016).

6.2 Social and Cultural Aspects

6.2.1 Local Māori History and Traditional Use

Ngai Tara, and later Ngāti Ira were the original inhabitants of the Wellington south coast, including Lyall Bay. However, migration, intermarriage and warfare meant that Ngai Tara and Ngāti Ira were absorbed into other neighbouring iwi. In contemporary times, Ngāti Awa, Te Ātiawa, and Ngāti Toa Rangatira all have shared vested interests in Lyall bay, or Hue-te-para as it is known by these iwi. These three iwi are represented by Te Rūnanga o Toa Rangātira, The Wellington Tenths Trust, and the Port Nicholson Block Settlement Trust.

As per Ngai Tara traditions (Pre – 1460AD), Lyall Bay was a channel called Te-Awa-a-Taia, not a 'bay' as we see today. Following the earthquake and uplift that occurred around 1460, Miramar Peninsula and Kilbirnie were connected by a sandy beach. This new sandy beach area was used as a 'tauranga waka' (an area to store canoes) for fishing and other such expeditions (Love, 2016). Moreover, Kilbirnie and Rongotai was still only sand until 1855, when another uplift and earthquake occurred (Love, 2016).

There are two pā sites at either end of Lyall Bay. Hue-te-Taka was situated above Moa point, which was an important fishing ground. The pā in nearby Kilbirnie, which overlooks the runway was named Akautangi (Love, 2016).

In more recent times, Lyall Bay is regarded as more of a recreational area (i.e. swimming, surfing) by local Māori (Love, 2016; Rei, 2016). However the reef systems on either side of Lyall Bay are important cultural landmarks, and other nearby areas such as Island Bay, Owhiro Bay, Moa Point, Turakirae, Te Tangihanga a Kupe (Barrett Reef) and Breaker Bay provide better fishing and shellfish (Love, 2016; Rei, 2016). In this sense, local Māori have a closer affinity to certain spots if they provide kai (food), if they house ancestral bones, or they are old pā (fortified village) sites. None of which apply to Lyall Bay (Rei, 2016).

All three local iwi are very supportive of the South Coast Marine Education Centre and other initiatives that focus on environmental and marine sustainability (Love, 2016; Rei, 2016). Future aspirations of local Māori regarding Lyall Bay include the continued recognition of pā and waahi tapu (sacred sites), and to continue working alongside the South Coast Marine Education Centre (Love, 2016).

6.2.2 Surfing and Surf Life Saving History

Lyall Bay Surf Life Saving Club was New Zealand's first patrol, starting in 1910. The Duke's visit to Wellington in 1915 makes the surfing population the oldest in the country. Charles Lake was one of the most prominent Wellington surfers in the 1950s, constructing his boards, and was heavily influenced by Mount Maunganui Surf Life Saving Club and the construction of surfboards coming from there in the late 50s. Peter Fitzsimmons was another distinguished Lyall Bay surfer, being a member of Lyall Bay Surf Life Saving Club and running The Corner Surf Shop from ‘65-‘75, and contributing to the start of the Wellington Surf Club in 1965 (Williamson, 2012).

Being located central to the country’s capital city, Lyall Bay is frequented by many recreational users including swimmers and bathers, jets skis and windsurfers.

Lyall Bay is one of Wellington’s most popular beaches and is a popular swimming spot during the summer months. The beach is generally safe for swimming during summer although cold. The beach slopes gently offshore and swimmers can get some distance into the sea before reaching water out of their depth. Southerly swells can create large dangerous breaking waves, strong rips/currents, sudden drop-offs and holes. While rips and holes are not common on the central beach, they do form around the headlands. In the 10 years from 2005 to 2015, 75 rescues occurred in Lyall Bay, with rips/holes being identified as a causal factor in 9.3% of these rescues[4]. The beach is patrolled by lifeguards over summer weekends from early November to late March, and there is a professional patrol for three weeks during January.

6.3 Surf Break Characteristics

Atkin et al. (2015) characterised and constructed swell corridors for Regionally Significant Surf breaks in the Greater Wellington Region. Figure 6.2 presents the probability of occurrence on schematised incident waves to Lyall Bay. Atkin et al. (2015) reported that there are at least ten distinguishable surfable waves in and around Lyall Bay, including big wave surfing locations. This project is only concerned with those waves breaking in the beach area.

An A-frame peak opposite the Lyall Bay surf clubrooms is the most dominant surfing wave during a south-easterly swell. Both a left and right-hander break from the same peak. The right-hander from this peak is considered of higher quality than the left. The left-hander breaks toward the swimming area and Maranui clubrooms.

“The Bend” is a right-hander that starts to break adjacent to Kingsford Smith St, with surf rides ending towards a midpoint between Tirangi Rd and Cochrane St. Lefts at “The Bend” break toward Onepu Rd. Sometimes the wave is unsurfable with waves closing out, instead of peeling.

[4] Rescue statistics from the Surf Life Saving New Zealand’s Patrols and Memberships database (PAM) for the ten years from 1 July 2005 to 30 June 2015.

"The Toilet Bowl" is in front of Cochrane St. This break is predominantly a left-hander, although it does produce a short wedged right-hander on occasion. "The Corner", a left-hander also known as "The Wall", breaks along the airport wall from a point south of the orange and white steel frame communication tower. "The Corner" is Lyall Bay's premier surf break. The above waves are beach breaks. "The Corner" is a modified beach break, whereby there is localised preconditioning of the wave caused by the interaction of incident wave crests with the sea wall.

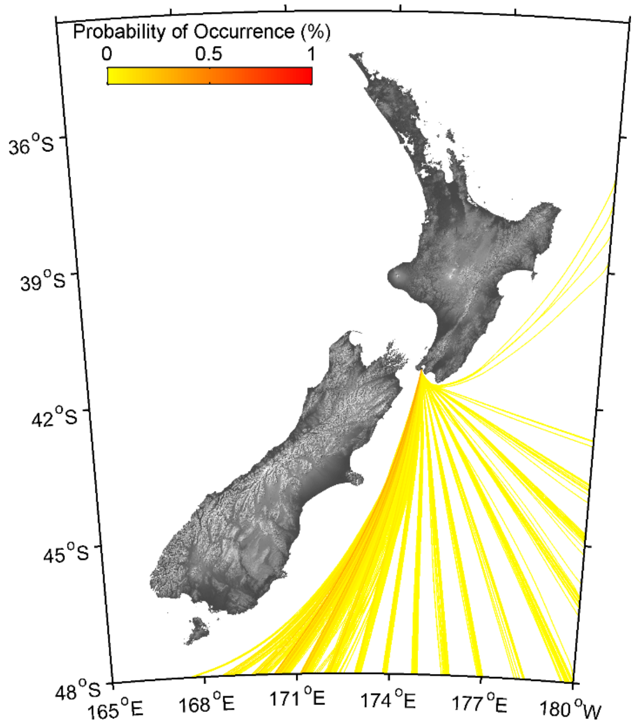


Figure 6.2: Probability of Occurrence plot of schematised wave conditions incident to Lyall Bay (Atkin *et al,* 2015).

Mortensen *et al.* (2015) showed through numerical modelling of 3 different swell scenarios that waves at "The Corner", "Middle Beach" (which includes "The Bend") and "West Beach" (includes the Maranui breaks) are surfable over a distance in excess of 230 m, 250 m and 290 m, respectively, under optimum surfing conditions. Under average surfing conditions, ride lengths were reduced but rides in excess of 130 m were still simulated. Under large wave conditions rides, in excess of 230 m, 270 m and 290 m for the 3 surfing locations were simulated.

Mead and Black (2001c) measured a vortex ratio value of 3.43 at Lyall Bay, putting the break firmly at the spilling end of the plunger breaking spectrum. Estimated orthogonal seabed gradients (which are likely to be equivalent to contour normal seabed gradients) were in excess of 1:35. While this high value for vortex ratio is representative of the bay in general (the evaluation was done on a right-hand wave breaking towards the bend), there is clear stakeholder feedback and photographic evidence of steep, high performance, barrelling waves within Lyall Bay, particularly those associated with “The Corner”.

Associated with the high vortex ratio assigned by Mead and Black (2001c), Lyall Bay, along with Fitzroy Beach (New Plymouth), Main Beach (Mount Maunganui), Wainui and Waikanae Beach (Gisborne), and St Clair Beach (Dunedin), were accepted as examples by the board of inquiry to the 2010 NZCPS as nationally significant nursery surf breaks.

6.4 Current and Potential Threats

In 2015, plans to extend the airport runway by 350 m were announced. This is the primary threat to the surf breaks as identified by stakeholders, followed closely by coastal erosion. Initial impact studies of the extension have indicated that the surfability of waves will be decreased by the extension (Mortensen et al., 2015). This is caused by a reduction in wave ‘peakiness’ due to the extension, which will have a consequent reduction in the number of surfable waves. The process of refraction tends to align wave crests to the seabed contours, resulting in waves that break simultaneously along the crest, or closeout, which is not conducive to good surfing – good surfing waves break in a peeling motion. Peakiness, or variable height along the wave crest, helps to ensure that waves do not close out – wave breaking is depth-limited, so when a wave crest has differential heights the highest part of the wave crest (the peak) will break before the other parts of the wave and result in peeling. If the peakiness is reduced, then the number of peeling waves conducive to surfing is reduced within the bay.

The results of model simulations with and without the airport extension for 3 representative wave events conducive to surfable waves within Lyall Bay (which were considered with input from the Boardriders) show that the western and middle bay are the most affected by the proposed airport extension (a reduction in surf rides is expected to be between 18-27% and 14-29%, respectively). The reduction in surf rides at “The Corners” is estimated to be lower by 4-8% (Mortensen, et al., 2015). In addition, the break called “Airport Rights” will be lost due to being covered by the airport extension.

Due to the direct reduction in wave peakiness, and so surfable waves, there are likely to be significant changes in wave-driven currents (as presented by both NIWA, (2015) and Mortensen, et al., (2015)), mostly inshore of the airport reclamation and in the vicinity of “The Corner”. These currents will impact seabed morphology, and consequently on surfing waves as they propagate shoreward; whether the impact will be negative or positive is currently unknown since this has not yet been investigated adequately.

It has been proposed that a ‘focus’ reef be constructed in the middle of the bay to mitigate the loss of surfing amenity that the airport extension will cause by creating more peeling waves.

Additional threats to “The Corner” surf break at Lyall Bay include ongoing modifications to the airport reclamation. Over the years, there is anecdotal evidence that has indicated that the reduced reflectivity of the reclamation has reduced the quality of this break, with the best surfing quality dating back to when the reclamation was sheet-pile (i.e. highly reflective); modifications such as the car park extension have had a detrimental impact, and the most recent widening of the toe of the rock revetment further decreasing the quality of the wave (J. Whittaker. personal communication, 2015). The impacts of these relatively small incremental developments on wave quality at “The Corner” indicate that a 350 m long extension and changes to current patterns and consequent sediment transport are likely to have profound impacts on the surfing conditions in Lyall Bay. However, the full extent of them and whether or not they will further reduce surf quality in Lyall Bay (as the reduction of peakiness has been indicated to cause), is presently unknown. This present project will provide the monitoring information to evaluate any future changes to the breaks at Lyall Bay, should the airport extension go ahead.

6.5 Summary

Lyall Bay is one of New Zealand’s oldest recognised surf breaks and is widely enjoyed by inhabitants of Wellington and surrounding regions. Surfing conditions are governed by the effect of shadowing by the headland and airport runway on the incoming wave conditions. Changes to the airport are the main perceived threats to the surf break, particularly the conditions along the runway.

7 Manu Bay

Manu Bay is located on the west coast of the North Island, to the south of the entrance to Whaingaroa (Raglan) Harbour. Manu Bay is one of 3 Nationally Significant Surf Breaks in Raglan. “The Point”, the seaward edge of the Manu Bay Reserve, has hosted national and international surfing competitions and is home to the Point Boardriders.

Stakeholders indicated that there is significant value, associated with the quality and consistency of the surf and the uniqueness of the environment, to have several high-quality surf breaks in close proximity to one another. Stakeholders also value the ease of access at Manu Bay, and that it is inclusive to surfers of all ages and abilities; it “provides the perfect steppingstone for intermediate surfers progressing from a "beach only" surfing experience”. The local topography at Manu Bay also provides an excellent viewing spot, which is also considered safe given the onlookers immediacy to the surf. Manu Bay is considered the heart of a large surfing community which families have built their lives around, without which Raglan would likely have remained a sleepy little town like many West Coast towns in the Waikato Region.

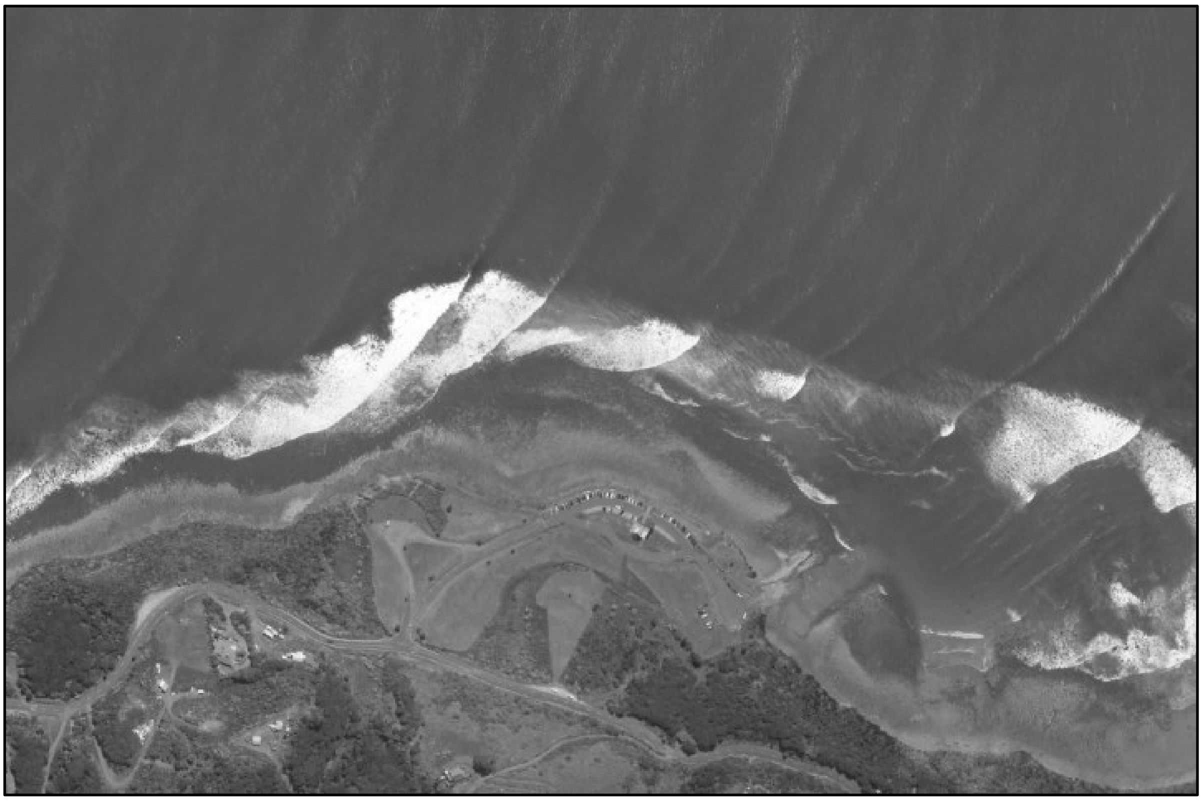


Figure 7.1: Manu Bay. (Source Land Information New Zealand Orthophoto archive, 20012-13).

7.1 Environmental Setting

The coastal landscape around Raglan is dominated by the ~750 m high Mount Karioi, an extinct volcano. Along with Albatross Point to the south, Mt Karioi presents a significant perturbation in the west Waikato coastline. From Papanui Point, the most westerly point of the Karioi area, around to Manu Bay, the coastline is largely a mix of steep, exposed cliffs, rocky reefs and boulders. East and north of Manu Bay, the coastline transitions and becomes more dominated by black titano-magnetite sand.

At the eastern end of Manu Bay, the presence of the boat ramp breakwater (Figure 7.2) has caused a large scour hole on the structure's western side resulting from increased offshore-directed currents induced by wave setup between the breakwater and adjacent land, and the wave reflections ("backwash") from the breakwater itself. The presence of the breakwater prevents the movement of boulders along the upper shore, leading to erosion on the eastern side of the boat ramp.

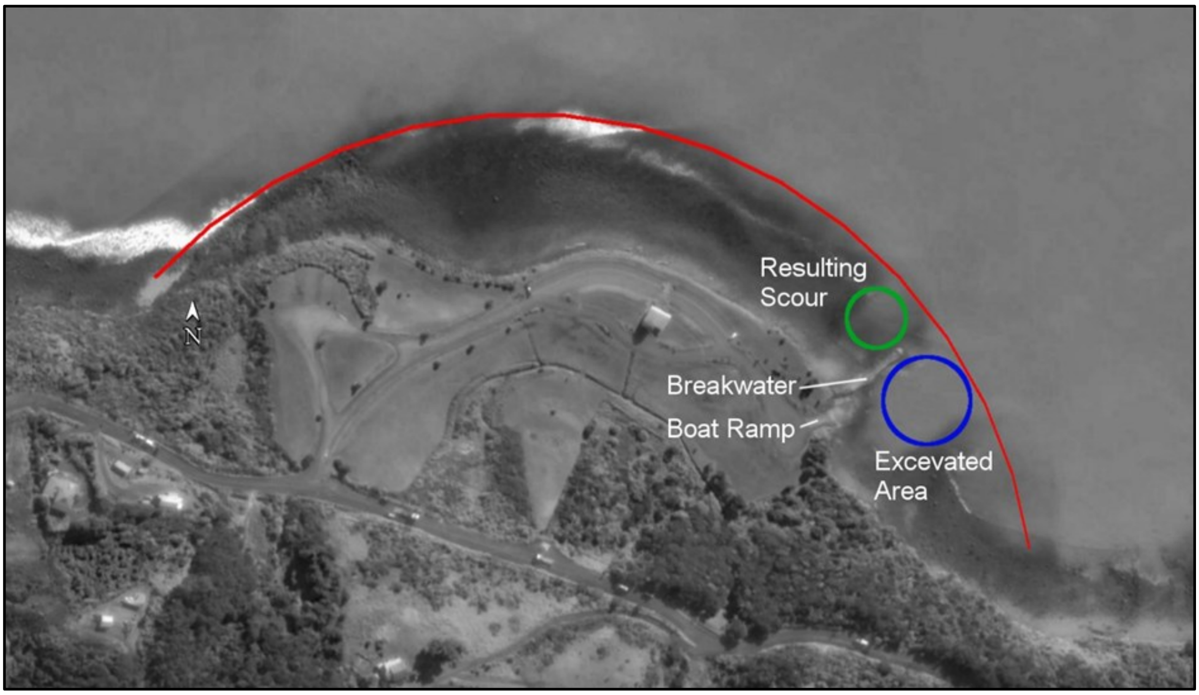


Figure 7.2: Annotated Google Earth image of Manu Bay.

There is a net, 175 000 m^3/yr of sediment moving on the seabed around the Raglan surf breaks (Phillips, 2004). This is made up of 275,000 m^3/yr in an easterly direction in the surf zone area, and 100,000 m^3/yr to the west further offshore in a recirculating sediment/current pathway. Considering the significant volume of sediment moving around the headland, any construction modifying currents (i.e. the breakwater) can cause morphological changes due to bathymetric steering of currents and impacts to surf zone hydrodynamics. During large swell conditions, strong wave driven currents, which would normally flow down the headland unimpeded, are directed offshore by the breakwater.

Scarfe *et al.,* (2009a, b) summarises the impacts of the breakwater and boat ramp construction on the Manu Bay surf break. The structures interrupt the natural fan-shape of the volcanic (andesitic) boulder field at Manu Bay some three quarters of the way along west to east. During construction, sub and intertidal substrates were excavated from a ~2,000 square metre area, creating a 50 m (approx.) wide gap in the pre-construction morphology.

7.2 Social and Cultural Aspects

7.2.1 Local Māori History and Traditional Use

Ngaati Hounuku/Te Paetoka hold manawhenua over Manu Bay. However, there are shared interests over Manu Bay with other nearby hapū who all come under the umbrella of Tainui Awhiro. The tribal groups of Whāingaroa (Raglan), namely Tainui, Ngāti Hounuku, Ngāti Ikaunahi, Ngāti Kōata, Ngāti Māhanga, Ngāti Hourua, Ngāti Tahinga, Ngāti Tamainupō, Ngāti Kōtara and Ngāti Te Huaki are the custodians and guardians of the nearby harbour, sea and waterways, of the land, and of the foreshore (Greensill & Ellison, 2010).

The original name of Manu Bay was Waikeri. Wai means water, and keri can mean 'dig out' or 'rushing'. Therefore, Waikeri means rushing water. At times, Manu Bay had a strong current that required careful consideration when entering the water. The name Manu Bay came from a person Manukapua. Manukapua fought as a rebel with local iwi. Manukapua was land-less, however he was gifted the area surrounding Waikeri, hence the name Manu Bay (A. Greensill. personal communication, 15th September 2016).

In ancient times, surfing was conducted by local Māori at nearby breaks. Competition was fierce, and whoever lost, would also lose their land (A. Greensill. personal communication, 15th September 2016). Mauriri was the name of one such competitor.

Manu Bay was once considered a pātaka kai (food storehouse), as various fish and shellfish were once in abundance. However, these stocks have since declined with nearby development, environmental changes and a rise in the local population.

In 1855 the Whāingaroa hapū gifted the nearby maunga Karioi to Queen Victoria whilst retaining a reserve for these local hapū. Despite this gift, eight years later they were labelled rebels and had 150,000 acres of coastal land at Te Akau confiscated for British settlers from the high-water mark inland (Greensill & Ellison, 2010). In 1874, 90,360 acres were given back as a Crown grant to say sorry for the theft of the 150,000 acres (Greensill & Ellison, 2010).

In contemporary times, and as surfers began arriving in Raglan, the interactions between surfers and local Māori was rather eventful. According to long time Raglan resident Malibu Hamilton, “we became self-centred on getting what we wanted, which was the wave” (Puriri, 2016).

“When we first started coming here, we would jump out of the car and down into the paddocks to get to the waves. In those days we didn’t ask. We didn’t have respect for the people that were here. …Surfers started abusing landowners as if they had a right to walk on their private land” (Puriri, 2016). However, relationships improved as Mr Hamilton and others sought to talk to local landowners about how to solve conflict issues and to police the surfers as well.

Although interactions have improved over the years, Mr Hamilton concludes that many surfers still disrespect the manawhenua and tangata whenua. “There are those who have learned and developed themselves to become better people through surfing. They have learned to understand Tangaroa, Tāwhirimātea and Tāne-mahuta, you know that those people are feeling the ocean, they are with the ocean, sharing it and sharing the atua” (Puriri, 2016).

Nowadays, Waikato-Tainui have a bi-annual surf competition held at Manu bay. It is open to all surfers who whakapapa to Waikato-Tainui. This whānau-centric event is not necessarily a competition per se, but rather it focusses on whanaungatanga (togetherness), participation, reaffirming cultural ties, and celebrating Waikato-Tainui identity.

7.2.2 Surfing and Surf Life Saving History

Efforts by Puriri (2015a, b) to document the origins of surfing in Raglan suggest the first waves surfed in the late 1950s. When Peter Miller first surfed Manu Bay in February 1960, he referred to the wave as “The Point”. From Puriri (2015a, b), it is evident that a relatively high number of people were surfing Manu Bay in the early 60s, travelling from Auckland, Hamilton and other parts of the country. Around this time The Raglan Point Boardriders Club was established.

The surf break was introduced to the global surfing community through Bruce Brown’s 1966 film “Endless Summer”. Raglan has produced several surfing champions and professional surfers and has a booming surf-based tourism industry. Daniel Kereopa is a “waterman”, successfully competing in shortboard, longboard, and stand-up paddleboard divisions, and undertaking big wave surfing (paddle and tow-in). Daniel won the inaugural Ultimate Waterman competition, defeating a selection of the world’s best watermen in 2015. The current high-profile surfer from Raglan is Billy Stairmand. Billy competes in the World Surfing

Leagues Qualifying Series and has ranked in the top 50 of some 1100 international athletes for the past 3 years. Billy has won 5 national titles in New Zealand.

During large conditions, the wave-driven currents at Manu Bay can become treacherous. An offshore directed current, colloquially known as the “Bombay Rip”, has been known to transport surfers away from the surfing area. Coastguard and SLSNZ responses to surfers in distress, often associated with this current are becoming more frequent (authors' observation).

Although there are no SLSNZ patrols at Manu Bay, Ngarunui Beach is a popular sandy beach a short distance to the east of Manu Bay that is popular for surfing during the summer. While the beach is sheltered to some extent by the headland large powerful surf and strong rips are common. In the 10 years from 2005 to 2015, 824 rescues have occurred on Manu Bay and Ngarunui Beach with rips/holes being identified as a causal factor in 80.9% of these rescues[5]. The beach is patrolled by Trust Waikato Raglan Surf Life Saving Club from Labour Weekend to Easter. During large wave conditions, inexperienced surfers can be swept up the coast from Manu Bay to Ngarunui Beach.

Figure 7.3: Historical photos of surfing and the point at Manu Bay (images courtesy of Puriri (2015 a, b)).

[5] Rescue statistics from the Surf Life Saving New Zealand’s Patrols and Memberships database (PAM) for the ten years from 1 July 2005 to 30 June 2015.

7.3 Surf Break Characteristics

Manu Bay is the last in a succession, from west to east, of several left-hand point breaks in Raglan that are comprised of volcanic (andesitic) boulders that fan out from above the high tide mark to form rocky/boulder reefs to depths of 3-6 m. From the toe of the reef, a sand platform extends offshore.

The point breaks at Raglan are beneficiaries of the headland effect (Mead and Black, 2001b), whereby the orientation of the headland acts as a wave filter, refracting the longer period waves in toward the surf breaks while letting other shorter period waves travel past and up the coast. The orientation of the breaks to the predominant swell and wind direction, the wave-filtering and the boulder reef substrate combine to make Raglan's points some of the best surf breaks in New Zealand (and the world) and justify their inclusion as Nationally Significant Surfing Breaks.

A headland is considered by Mead and Black (2001c), at a macro scale, as a large wedge component, that extends into deep water. This largely sand bottom feature pre-conditions waves prior to breaking at the point breaks. The bathymetric configuration at Manu consists of a mesoscale scale wedge, with a 3,200 m² (Scarfe, 2008), superimposed ridge feature at the westerly end of the point which forms a part of the break known as "The Ledge", which is known to produce intense breaking waves (i.e. barrels or tubes – See Appendix A). Scarfe (2008) states that the main wedge is actually two wedge components, separated by a platform, and function differently during different swell and tidal conditions. The two wedges are approximately 30,000 m² (shallow shelf/wedge) and 40,000 m² (deep shelf/wedge) in size. The platform between the two wedge components is approximately 50 m wide in the offshore regions and expands to 80 m wide eastward, pushing the lower tide waves offshore. Hutt et al., (2001) determined orthogonal seabed gradients as high as 1:7 at Manu Bay – which is assumed to be in association with "The Ledge" area.

The boulders and reefs along the point result in a steeper beach gradient than occurs with the fine-grained sands in the area, which has the effect of increasing the breaking intensity of waves. Mead and Black (2001c) evaluated Manu Bay to have a vortex ratio of 2.89, indicating a medium breaking intensity on the Mead and Black (2001c) classification scheme (note, this investigation did not focus on "The Ledge", which has a significantly lower vortex ratio). From aerial photographs, Hutt et al., (2001) measured peel angles at Manu Bay between 30-75°, with lower (faster breaking) angles across "The Ledge", and increasing thereafter. Both the peel angles and vortex ratios have been shown to vary along the length of the surfable wave (Scarfe, 2008).

Scarfe (2002) showed with a time series of surveys at Manu Bay that up to 0.5 m thickness of sediment can be eroded and accreted per month from sand bars as they move onshore and offshore. This significant change in the shape of the sea floor over time affects the preconditioning of surfing waves. Meso-scale focus components were seen to appear and disappear over time as successive swells accumulated or scoured around the reef.

Manu Bay receives a very broad range of swell directions, but with the most common surfing conditions approaching from the southwest (Atkin and Mead, 2016) – allowing the headland to work to full effect (Mead and Black, 2001b).

7.4 Current and Potential Threats

The original boat ramp at Manu Bay consisted of simple timber retaining walls (Figure 7.4), and the wave was reported to have been surfable to the east end of the bay (Puriri (2015b; Stakeholder Feedback, 2016). In the late 1960s, the contemporary boat ramp and breakwater at Manu Bay were first constructed. The infrastructure has undergone routine maintenance since its inception. Following structural failures at the seaward end of the breakwater, in 2016 the breakwater was replaced with a new structure. The new breakwater is inside the original breakwater's footprint on the north-western side, and outside the existing footprint on the south-eastern side, due to the proposed design being linear, rather than bending northward. The design height and width of the breakwater are consistent with the original, although the flanks of the breakwater are less steep than the original.

Figure 7.4: Early boat ramp at Manu Bay (Image courtesy of Puriri (2015 b)).

The installation of the breakwater, boat ramp and associated excavations has had a negative impact on the surf break of Manu Bay. The new breakwater configuration is reportedly improving surfing conditions in the lower sections of the wave. The stakeholder workshop highlighted that it is important that any further maintenance should include an evaluation of the potential impact on the surf break. Stakeholder feedback reported that the biggest threat to the surfing amenity value of Manu Bay is not having the voice of the local surfers heard during decision-making processes, with the management of the recreational space and access points to the surf being a consistent theme, and the attitude towards the Point Boardriders Club a point of irritation. There are concerns over the sharing of space with both surfers and recreational boats using the boat ramp for access and, at times, occupying the same spaces away from the boat ramp.

Other observations from the stakeholder meetings and surveys included: septic or sewage spills occurring within the reserve, major concerns about water quality and ecology of the area (with specific notes about the odour and colour of the water); and the rocks that make up the boulder point becoming increasingly hard to access due to the slipperiness of the rocks. Certain respondents also voiced concerns regarding the number of users both in the surf and of the boat ramp facilities; other respondents' feedback considered parking and access an issue with a desire to keep Raglan “small and unique”.

7.5 Summary

In summary, the Manu Bay surf break has considerable cultural and social significance. Its unusual left-hand break attracts tourists and new residents to Raglan and has been featured in overseas surfing films. The main threats are changes to the boat ramp constriction and water quality issues associated with the ocean outfall.

8 Piha

Piha Beach is located on the west coast of the North Island, some 30 km west of Auckland. The ~2.75 km long beach composed of fine black sand is partially split in to North and South Piha by the iconic Lion Rock. This project is concerned with “South Piha”, the section of beach south of Lion Rock (Figure 8.1).

Piha stakeholders value the general beach environment greatly viewing it as a global attraction, but are also aware of Piha’s national and international recognition as a venue for surfing contests, and the quality of the wave, the latter being “crucial to surfing as a sport in New Zealand”. Stakeholders are also very aware of the dynamic nature of this west coast beach, noting it changes every day. Some note its proximity to Auckland as an important factor - this break was included by scoring highly in the “Dependent Population” category during the decision-making process of which breaks to include in the study.

Figure 8.1: South Piha (Source: Land Information New Zealand orthophoto archive, 2012-13).

8.1 Environmental Setting

The black sands of Piha came originally from the andesitic volcanic rocks of Mt Taranaki some 300 km south along the coast and also from the Taupo Volcanic Zone (via the Waikato River) along with some sand from local streams and cliff erosion. Sand from these sources is transported along the coast by longshore currents generated by the large and prevailing south-westerly swells originating in the Southern Ocean.

Sand has been coming ashore at Piha ever since the sea level rose to its present level approximately 6,500 years ago. At that time waves were washing against the rock cliffs that are now behind the dunes at Piha. Sand driven ashore since that time by waves and wind has filled the bay and built the beach, dunes, and sand banks in the nearshore. Sand has also accumulated behind the dunes where sheets of sand are piled against the hills and are now covered with bush and forest.

The northward littoral drift brings sand around the southern headland and into the bay. However, not all the sand arriving at Piha stays in the bay. The energetic waves typically have long periods and reach 1.5 to 2.5 m in height (up to 6.5 m in storms) and the zone of wave breaking, in which sediment transport is maximised, can extend some 500 m offshore. These conditions generate strong longshore currents and rips and transport sand around promontories like Lion Rock and allow sand to bypass the headlands and leave the bay. The net result is that sand accumulation in the bay is cyclic which sees the sand banks change position and the dunes build out and cut back at varying time scales.

There is evidence that there has been rapid progradation (building seaward) of the dune system over the last century. At North Piha, the shoreline and dunes near Takatapu (Monkey Rock) have built about 150m seawards of the cliffs, with 70 to 120m of this progradation happening in the last century (King et al. 2005). Photographs taken in about 1900 show the tide lapping around the rock and the sands dune well landward of the rock. Today the foredune is seaward of Takatapu. Mapping shoreline change from aerial photos shows that the shoreline at Piha advanced seawards at an average rate of 0.4 to 1.0 m/yr between 1940 to 2000 (King et al., 2006).

South Piha Beach is around 500 m in length. The Piha Stream, which flows down from the Waitakere Ranges, discharges adjacent to Lion Rock, at the north end of South Piha. Further south, the Moana stream also discharges onto the beach. Hume et al., (1999) report that the Piha Stream flows south of Lion Rock, roughly 80% of the time. The stream flow direction across the beach can be to the north, south and anywhere in between and is largely a function of sand deposition in the lee of Lion Rock. The Moana Stream is trained and discharges onto the beach. Further down the beach, however, the stream roams and meanders in time, and has the capacity to cut the toe of adjacent foredunes.

8.2 Social and Cultural Aspects

8.2.1 Local Māori History and Traditional Use

Te Kawerau a Maki are the tangata whenua of Hikurangi (West Auckland), and hold manawhenua over the region. Te Kawerau a Maki has existed as a distinct tribal entity since the early 1600s when the eponymous ancestor Maki and his brother Matāhu conquered and settled the Tāmaki isthmus and the wider area including what is now known as Waitakere City (Taua, 2009). Nevertheless, earlier ancestral links and subsequent intermarriage with the earlier inhabitants occupying the district, Te Kawerau a Maki have direct ancestral connections since human occupation began over 800 years ago (Taua, 2009).

According to local traditions, the Piha area has been occupied since the time of Maui the demi-god, prior to the arrival of ancestors from Hawaiki (Knox, 2016). Waitakere City was originally named Te Wao nui a Tiriwa, named after the turehu rangatira (supernatural being) and Te Kawerau a Maki ancestor, Tiriwa (Taua, 2009).

Ancient taniwha live on and remain as kaitiaki (guardians) of great spiritual significance to the Te Kawerau a Maki people. One such taniwha is Paikea, a guardian of the Waitakere coastline (including Piha) and the Manukau Harbour entrance (Taua, 2009). Kaiwhare is another taniwha who oversees the area between Muriwai and Manukau harbour (Turei, 2011). Te Kawerau people retain karakia (ritual incantations) associated with these taniwha to ensure that the spiritual essence endures.

Upon the arrival of Tainui waka to what is now known as Auckland, the renown ancestor Rakataura (known to Te Kawerau a Maki as Hape) explored the area, and many landmarks there still bear the names given by him. For example, Hape named the mountain range within which Piha is located Hikurangi; and Piha Stream is known traditionally as Te Wai o Kahu, named after Hape's wife (Knox, 2016).

Furthermore, there are many pā and wāhi tapu along the west coast, including at Piha, which are of great historical significance to the Te Kawerau a Maki peoples (Knox, 2016). Whakaari, otherwise known as Lion Rock was a famous pā site of Te Kawerau a Maki, and is still an iconic bastion of their identity. Some years ago a pou whenua (marker post) was erected there in memory of their ancestors. Other pā included Te Wahangu which was on the headland at the north end of the beach, Maungaroa on the ridge above the lagoon, and Otokitoki on the headland halfway along North Piha beach (Coney, 2016a).

In more recent times, the Piha Native Reserve was one of the final land blocks that belonged to Te Kawerau a Maki, following the alienation of most of their lands via the various colonial machinations (Knox, 2016). Taitomo Island ('the gap' at the south end of Piha) still remains in customary title – and prior to the Treaty settlement, this was the only land still owned by Te Kawerau a Maki within Te Waonui a Tiriwa. The hill to the south of Taitomo Island was traditionally used by Kawerau a Maki fishing parties and there are midden sites, terraces, pits, and rock and cave shelters all around the Piha area (Knox, 2016).

The future aspirations of Te Kawerau a Maki in regards to Piha are similar to other areas within the Hikurangi region, and include (Knox, 2016):

- Protection of wāhi tapu and other cultural heritage features
- Protection of natural taonga (treasures), flora, fauna, waterways in exercising our role as kaitiaki
- Retention of korero tuku iho (traditional knowledge) relating to the area
- Eventual resettlement of the area by Te Kawerau a Maki descendants.

8.2.2 Surfing and Surf Life Saving History

Piha is credited with being the birthplace of the modern surfing movement in New Zealand. While wave riding was undertaken previously, the sport in New Zealand evolved in 1958 when two US lifeguards, Rick Stoner and Bing Copeland, brought malibu boards to Piha.

Piha is considered to be a very hazardous beach. Coney (2016b) provides a detailed description of the history of surf lifesaving a Piha, which, in 1934, was the first surf club established on the West Coast. Since that time the club has been a leader in surf lifesaving development by importing a surf boat from Sydney, holding the first surf boat race to be held in New Zealand in the 1930s, introducing surf skis as rescue craft, inaugurating the rescue helicopter service (now the Westpac rescue helicopter service) and the jet boat and trialling and developing the IRB. The club performs more rescues annually than any other club in New Zealand.

Piha has produced numerous high-profile surfers from Peter Way, who won the senior men's section in the inaugural national surfing champs in 1963, and represented New Zealand at the world championships in Puerto Rico in 1968; to Elliot Paerata-Reid who represents Piha and New Zealand on the World Qualifying Series of the World Surfing League. Piha Surf School

(2016) provides a comprehensive and extensive list of all the accolades that surfers local to Piha have achieved since the early 60s.

In the mid-20th century, there were several, possibly unofficial, clubs or groups of surfers frequenting the waves at Piha. In the mid-70s, the Piha Surf Club was established. There are two Boardriders groups, Piha Boardriders (formerly Wildcoast Boardriders) was formed in 2001, and Lion Rock Boardriders. The survey feedback showed Piha stakeholders are very proud of their surfing and surf lifesaving history.

Piha is considered by Surf Life Saving New Zealand as a very hazardous beach for swimmers with large breaking waves, strong rips/currents, sudden drop-offs and holes, and unstable cliffs. The low to moderate gradient beach is fronted by an attached inner bar, then a steep trough and an outer bar that lies between 250 and 350 m seaward of the beach. Large waves that can break 500 m and more offshore, produce strong currents that flow out as permanent rips against the southern headland (the “Patiki Rip”) and Lion Rock. There are also rips spaced approximately 500 m apart along the beach. In the 10 years from 2005 to 2015, 880 rescues have occurred on Piha Beach (south of Lion Rock) with rips/holes being identified as a causal factor in 76.1% of these rescues[6].

8.3 Surf Break Characteristics

Piha South is host to 4 recognised breaks, namely, “Piha Bar”, “Inside Bar”, “The Ditch” and a wave referred to by some as ‘The Hass”, or “The Hassle”. The different breaks loosely represent the different surfing options throughout the tide, from low to high, respectively.

Piha Bar is a left-hander that under optimum conditions breaks from adjacent to Taitomo Island (also called “Camel Rock” or “The Beehive”) across the bay toward Lion Rock. Piha Bar is considered best at low tide. Inside Bar, which is landward of Piha Bar, provides lefts and rights and is regarded as a wave best surfed during a flooding tide, from mid-tide onwards. Further landward of Inside Bar is the Ditch, a high tide “reform wave”, where waves, previously broken on outer seabed features, are restored to a pre-breaking condition.

The Hass, located adjacent to Lion Rock, is considered a fickle surf break, which like the other surf breaks at South Piha, is largely dependent on sediment and sandbank movement, which in turn are a function of incident wave climate and the streams that discharge on to the beach, as well as bulk sediment input from sand moving up the coast. This flux of sand in and out of

[6] Rescue statistics from the Surf Life Saving New Zealand’s Patrols and Memberships database (PAM) for the ten years from 1 July 2005 to 30 June 2015.

the bay and the resulting changes in the configuration of banks and rips have a continuing impact on surfing conditions.

Piha has almost no field data and investigative documentation concerning the surfing conditions. Figure 8.2 presents annotated Google Earth images and shows potential peel angles ranging from 50 to 80°. Figure 8.3 and Figure 8.4 are still images captured from videos posted online of surfing at Piha Bar. They show waves with Medium to Medium/High breaking intensities (Mead and Black, 2001c), with some “tubing sections”, and open faces suitable for high-performance manoeuvres.

Figure 8.2: Peel angles annotated on Google Earth imagery for August 2008 (Top Left), November 2014 (Top Right) and December 2015 (Bottom).

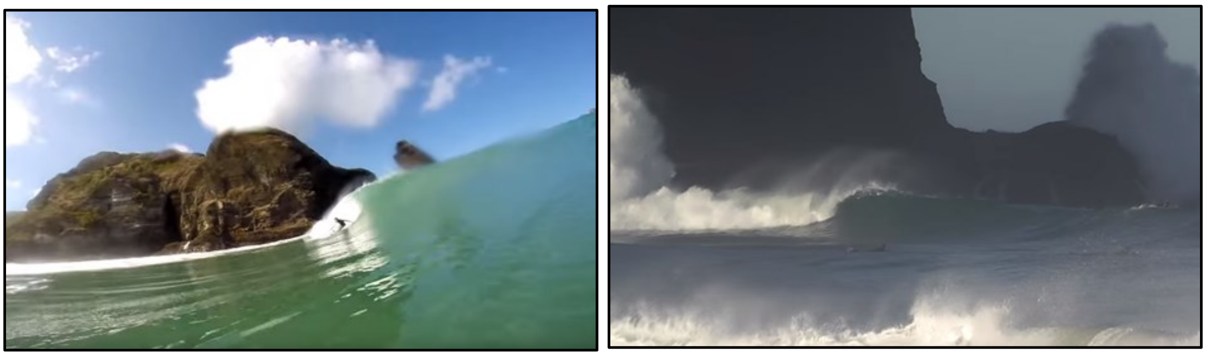


Figure 8.3: Still images captured from video of Piha Bar in 2014 (Footage courtesy of Piha Surf School, 2014).

Figure 8.4: Still images captured from video of Piha Bar in 2014 (Footage courtesy of Monks, 2014).

8.4 Current and Potential Threats

Current threats to the surf break at South Piha are perceived by stakeholders as coming from: 1) an increased influx of sand into the bay resulting in continued shoreline accretion and associated changes to the configuration of rip channels and sandbanks offshore and 2) sand being locked up in the dunes and unavailable to form sand banks offshore. A potential future perceived threat is the possibility of offshore seabed sand mining of iron sands. Extraction of large quantities of sand from the seabed is perceived to threaten the supply of sand to the beaches and banks offshore. The pits and mounds left on the seabed by mining can cause changes in the characteristics of waves travelling through the mining site, and therefore, potentially affect surf break conditions (Mead, 2013).

Current threats are evidenced by anecdotal information and surveys of the beach and dune areas showing that the dunes along the shore are prograding seawards. There are conflicting viewpoints regarding the cause and effect: with some believing that the dunes growth has pushed subtidal banks to move further offshore; whilst others have observed that large volumes of sediment arriving at Piha from offshore are filling the bay, and in turn resulting in upper beach accretion and dune growth (McNeil, 2016).

Regardless of the mechanism, anecdotal evidence suggests that sand has infilled the Pakiti rip channel to some extent. It is reported that these effects have altered the circulation pattern close to shore and that sand is no longer flushed from the area and deposited on Piha bar, resulting in a detrimental effect on the quality of the surf break. The extent to which these effects are natural versus anthropogenic is debatable.

Further, the accretion or seaward advance of the Piha shoreline has adversely affected 'The Ditch', whereby wave energy cannot propagate further into the embayment and have a chance to 'reform'.

Dune conservation works in the form of dune re-shaping and planting to combat coastal erosion and stabilise dunes have certainly encouraged the growth of dunes to the extent where they have prograded seawards and grown taller and are, in places, obstructing views. Some stakeholders feel that the dune planting programme was not a requirement and was conducted without proper community consultation. Furthermore, the anthropogenically stabilised dune prevents the natural, wind-driven, back-and-forth migration of sand. It is perceived by some that while the sand is locked up in the dunes it is no longer available to build the sand banks offshore and therefore having a detrimental effect on the surfing conditions. Others consider that since the volume of material in the beach compartment has increased, the strength of the rip current system that forms Piha Bar has been reduced.

The influx of sand into the bay to build the dunes and infill channels could also be natural. Dune progradation over longer time scales is occurring all along Piha and not just in the areas where conservation efforts have taken place. There is anecdotal evidence, supported by opinion presented at the stakeholder meeting, that the influx of sand into the bay is part of pulses of sand driven north along the coast by the waves, as evidenced by progradation occurring first at Karekare Beach and then at Piha.

Water quality is not seen as an issue at this surf break by workshop participants.

The potential threat of offshore sand mining is evidenced by prospecting permits being granted for the Wanganui to the North Cape region of the west coast. Also, Trans-Tasman Resources Ltd have undertaken extensive studies of the black sand seabed resources off the South Taranaki Bight and are in the process of applying for permits for large-scale mining of the seabed for iron sands. The iron-sand resources of the west coast of the North Island are some of the largest of this type in the world (Brathwaite, 1990). The onshore deposits include the present beach and dune sands and there are also vast quantities of iron sands on the inner continental shelf. Two land-based mining operations already exist in the northern region, at Port Waikato and Taharoa.

Other threats perceived by stakeholders include the potential impacts of any oil spills, and most certainly the number of users in the area, particularly tourists. The increased number of users are considered a steppingstone to further coastal development and housing; potentially meaning more waste and pollution. There are concerns that visitors have a lack of respect for the beachscape and require education.

8.5 Summary

Situated near New Zealand's largest city, Piha has always attracted a large cohort of surfers. The main perceived threats to the surf break are the dune planting activities, natural changes to the supply of sand and stream channels, and offshore mining of sediment.

9 Wainui

Wainui Beach (Figure 9.1) is situated 6km north of the city of Gisborne on the east coast of the North Island. It has a population of approximately 1500 people, many of which are attracted to the beach by the excellent surfing conditions. The number of tourists visiting Wainui beach has increased steadily over time. The area is characterised by two substantial reserves, the W.D.Lysnar Reserve and the Wainui Beach reserve (Gisborne District Council, 2008).

Stakeholders indicated that the community have a traditional history of ownership, use, and protection and that, currently, the local council supports the natural setting. There are also aspirations that the current management of Gisborne's surf breaks can be used as examples of how surf breaks and the coastal environment can be managed.

Figure 9.1: Wainui Beach surf breaks (Source: Land Information New Zealand Orthophoto Archive, 2012-13).

9.1 Environmental Setting

Wainui Beach extends about 6 km between the rocky headlands of Tuahine Point to the south and Makorori Point to the north. It has an approximate northeast-southwest alignment to the Pacific Ocean and receives ocean swell from a wide north-to-south sector. The beach is backed by a substantial dune system. Two streams flow out onto Wainui Beach; Wainui Stream to the south, and Hamanatua Stream in the middle.

Offshore from the points, reefs extend to approximately 30 m water depth. It is thought that the seabed sediment, consisting largely of fine to medium shelly sands offshore grading to coarser sand on the beach, is trapped between the reefs. Between the reefs and out from the centre of the beach, the seabed contours are smooth and nearly parallel and sediment patterns may indicate a sediment drift north-eastward. Petrographic analysis shows the likely source of sand are the shore platforms and offshore reefs, combined with remnant ash deposits from the central volcanic region. In the nearshore, the seabed of the surf breaks is known to be comprised of sandy material overlying a rocky reef formation. There is a prehistoric forest along the northern side that is exposed during erosion events.

Wainui Beach is characterised by typical rhythmic topography and rip currents are common, especially when the currents are directed southward. Localised erosion is associated with large rip embayments. It is likely that the reefs offshore focus wave energy which leads to variable wave heights along the beach, which in turn creates the complex and varying rip cells that are conducive to good surfing conditions. As swell directions change, so do the rip cells in response, with different swell directions leading to different rip cells and consequently impact on surfing wave quality.

The Wainui Beach erosion management strategy (Gisborne District Council, 2014) describes the various works located along the beach to protect against erosion. In the south near Tuahine Crescent, there is a 175 m long, rock wall and groyne structure. In the area of Wainui Stream, there is erosion due to stream flows and migrating stream movements. There are timber seawalls along the esplanade reserve, the southern edge of the stream and within private properties to the north. Near Hamanatua Stream, where the shoreline is also affected by stream processes, there are timber stream training works to the south of the surf club.

9.2 Social and Cultural Aspects

9.2.1 Local Māori History and Traditional Use

Ngāti Oneone and Ngāti Rakaiatane are the kaitiaki for the Kaiti and Wainui area. They are committed to looking after the local environment and areas of cultural significance. The name Ngāti Oneone originates from an episode when an ancestor was once blinded by sand, hence the term 'oneone' (sand) (Tupara, 2016).

The first inhabitants of Wainui were those who arrived on the Horouta canoe. Horouta landed in Turanganui A Kiwa (Gisborne) around 1350 AD. The sacred calabashes holding the gods and taonga carried on the canoe were deposited in the Kohurau caves located in the Maungaroa headland at Wainui (Searancke, 2016). Uenuku Whakarongo, a chief on the Horouta canoe settled at Wainui over-looking the beach at the base of Maungaroa. He established and presided over the Wharekorero House of Learning, a place of supernatural powers. The present day urupā (cemetery) at Wainui is named after a magical feat Uenuku Whakarongo performed, 'Rakau a Ue' – the tree withered by his incantations (Searancke, 2016). Today Rakau a Ue on Tuahine Crescent is the final resting place of the descendants of Rakaiatane.

There are a number of areas of cultural significance within the vicinity Wainui. The river near Pines surf break is Hamanatua – upstream from here they would wash the bodies of the deceased (Tupara, 2016). Inland from Wainui beach are a number of ancient pā (Searancke, 2016; Tupara, 2016).

Heading north from Pines surf break is Okitūpāpaku (commonly known as Okitu). In ancient times the remains of the deceased would be hung to dry along the beach at Okitūpāpaku, or as a stop off point to cool the body down in the sea water so that it would last the journey north or south (Tupara, 2016). Hence the term 'tūpāpaku' (body of the deceased) (Tupara, 2016).

In traditional times, Wainui beach was not necessarily a recreational or bathing area for local Māori. Its main usage was to fish for sharks, a place for burials, and a thoroughfare to travel further up the East coast (Tupara, 2016). In the 1800s and 1900s local Māori hunted sharks (Great Whites and Mako) for sport and of course to eat dried shark, a traditional food of the local Māori (Searancke, 2016). Ika-Hoia is a local katiaki (protector/guardian) of Wainui. Ika-Hoia resides at Waihora reef.

Whānau in those times would launch canoes from the 'Pines' surf break and a current would take them to Toka Ahuru (Aerial reef), and then onto Mahia (Tupara, 2016). Some fishing waka fleets would row to Toka A Huru from Makorori beach, because it is closer in nautical miles. The closest reef in Wainui is the Tuaheni Reef, used for fishing and cray potting (Searancke, 2016).

In contemporary times, Wainui beach continues to be enjoyed by Ngāti Oneone descendants and other Māori as a recreational area for surfing and gathering kai.

9.2.2 Surfing and Surf Life Saving History

The Wainui Surf and Surf Life Saving Club was formed in 1937, with locals being successful in both disciplines (Meade, 2014; Clapham, 2016a). As with much of New Zealand, Wainui Beach surfing established itself in the mid-50s and early 60s. Clapham (2016a) describes a surf culture heavily influenced by touring Australians bringing high performance. Australian Bob Davie instigated the formation of a board riders club in 1964, with Des Byrne as the first president; the Gisborne Boardriders created a very competitive environment, nurtured by local business (Meade, 2014), which persisted through the late 20th century and beyond (Williamson, 2012).

The Gisborne area has produced numerous surfing champions, most notable of which are Maz Quinn, a four-time national's winner, 1996 Billabong Pro-Junior winner, and World Surfing League Qualifying Series and World Championship Tour surfer – the first New Zealander to achieve this accolade; Maz's brother Jae and sister Holly are both national title winners, Jae securing 3 national titles and winning the world junior title; Alan Byrne, multiple national titles and 2nd place at the 1981 Pipeline line Masters.

Wainui Beach is very popular with all recreational users, but it can be very dangerous. At times of large waves rips and holes are common. In the 10 years from 2005 to 2015, 56 rescues occurred at Wainui Beach with rips/holes being identified as a causal factor in 57.1% of these rescues[7]. Wainui Beach Surf Life Saving Club patrol the beach over weekends and public holidays during summer and there are also professional Lifeguards during the school holidays.

9.3 Surf Break Characteristics

Wainui is renowned for producing steep, powerful, hollow waves, and is home to several New Zealand surfing champions and providing World class surf breaks within 5 minutes of the city centre. "Pines" is one of multiple "peaks" located along Waiuni Beach that include (from south

[7] Rescue statistics from the Surf Life Saving New Zealand's Patrols and Memberships database (PAM) for the ten years from 1 July 2005 to 30 June 2015.

to north): “Stockroute”, “Schools”, “River of Life”, “Pines” (basically a reef break covered in sand, and predominantly a left break), “White Fence”, “Chalet/Rendezvous” and “Whales”.

Pines, the focus of our studies at Wainui, is located fairly centrally on Wainui Beach, close to the Surf Life Saving New Zealand clubhouse, where the Hamanatua Stream meets the beach. The amount of material present on top of the underlying rocky reef varies both along the length of the beach, but also in time. The resulting waves at Pines are a mix of left and right-handers, or “A-frames” which break both ways. There is a bank offshore called “Coopers Bank” that conditions waves, which merge toward the south with Te Toko A Huru reef.

Surfing conditions at Wainui are enhanced by the wide, north-to-south, sector through which ocean swells can enter the embayment and by the predominantly offshore (north-westerly) winds. At the shore, rips change the swell angles causing the breaks to shift in orientation and location. Surfing at Whales and Lone Pines tends to be better in summer. It is reported that Pines has not been good for several months (April 2016) but is getting better, although this site still provides powerful waves even when the break is not good quality.

There is no quantitative information concerning the wave quality at Pines. The sparse images available from Google Earth are not sufficient to estimate peel angles. This reinforces the dynamic and intermittent nature of the break at Pines. Figure 9.2 shows steep and hollow waves at Pines, with surfers provided the opportunity to execute high-performance manoeuvres.

Figure 9.2: Waves breaking at pines images courtesy of Jose Borrero (top), Clapham (2016b; bottom left) and The Gisborne Herald (2014; bottom right).

9.4 Current and Potential Threats

The Wainui Beach erosion management strategy (Gisborne District Council, 2014) describes that, based on historic trends, the beach exhibits a dynamic shoreline with rapid erosion events followed by a slow rebuilding of the dunes (accretion). It is expected that future erosion processes at Wainui Beach will continue to be dominated by storms and rip currents. Erosion is primarily seen as a risk for property rather than human safety. There are 113 beachfront properties south of Hamanatua Stream within the coastal hazard zones mapped in the District and Coastal Plan. Of these 113 properties, 28 have dwellings within the Extreme Hazard Zone and the area that is, or is likely to be, subject to adverse effects from short-term dune-line fluctuations and storm cuts.

Dunn (2013) describes the main coastal processes responsible for surf break formation at Wainui Beach and the measures required to protect the surf breaks. The report cites the key coastal process requiring protection as being the natural offshore and alongshore movement of sand, between the dunes and beach, and also between the beach and offshore seabed and that this applies to the entire sandy shoreline of Wainui Beach, not just the surf break locations. The report also expresses the opinion that, while it is not possible to make a conclusive statement on the impacts of current protection structures on Wainui surf breaks, it would appear that in the Stock Route area, the existing emergency rocks (rip-rap) do not appear to be affecting the surf breaks. The report warns that current literature on coastal protection and surfing provides the following key messages: 1) the potential impacts of coastal protection structures on surfing resources are poorly understood and rarely quantified; 2) a range of coastal activities and structures can alter or destroy surf breaks and the wave quality via the processes of wave reflection (backwash), wave refraction, blocking effects, and modified sand transport; and 3) surf breaks are near impossible to replicate or repair once they have been destroyed. It also adds that dune care or coast care planting will assist surf breaks by building the dunes and enhancing the store and buffer of sand required (the storm 'cut') during storm events. Dune planting will not prevent offshore and alongshore sand movements, only increase the volume of sand along the shore.

Multiple stakeholders reported water quality issues associated with the Hamanatua Stream, which discharges onto the beach near Pines, attributing the issue to the catchment being largely comprised of farmland.

9.5 Summary

Wainui Beach has long attracted surfers to the Gisborne region, and the beach and its surrounding reserve land have considerable social and cultural value. The main perceived threats to the break include changes to building and access, water quality issues, and natural variations to the wave and rip current conditions.

10 Whangamata

Referred to as a "Jewel of the South Pacific" by surfing legend Gerry Lopez (1975), Whangamata Bar is one of 17 Nationally Significant Surf Breaks (Department of Conservation, 2010). "The Bar" lies at the entrance to the estuary at Whangamata (aka Whangamata Harbour), on the east coast of the Coromandel Peninsula. The northern shoreline of the estuary has been designated as an area of high natural character in the Thames-Coromandel District Plan, with the northern edge and terminal lobe of The Bar included within the adopted area (TCDC, 2016).

Figure 10.1: Whangamata Beach (Source: Land Information New Zealand Orthophoto Archive, 2012-13).

10.1 Environmental Setting

Whangamata is located on the east coast of New Zealand. The beach is ~4 km in length, with the northern and southern ends demarked by Te Karaka Point and Te Teko Rocks, respectively. In the middle of the beach, a salient protrudes seawards in the lee of Hauturu Island and a few other smaller islands and offshore reefs. There are tidal inlets at both ends of the bay. The Otahu River is found at the southern end and the estuary is much smaller than its counterpart at the northern end, the Whangamata Estuary. The estuaries are barrier-enclosed by a Holocene spit (Sheffield et al., 1995), forming a dune barrier beach (Dahm and Munro, 2002), a feature not uncommon on the Coromandel Peninsula. The Whangamata Estuary was categorized by Hume and Herdendorf (1993) as a type 4, single-spit, barrier-enclosed estuary, the valley of which was originally cut by rivers when sea levels were lower and subsequently flooded when sea level rose some 6,500 years ago.

The ebb tidal delta is a body of sand formed outside the entrance to Whangamata Estuary. Here the outgoing tide (the ebb tidal jet) emerges from the narrow entrance and expands over a wide area and, as current velocities drop off, they lose their capacity to carry sand which is deposited on the seabed to form banks (the ebb tidal delta). This sand body is attached to the beach to the south, but separated from the headland by the main tidal channel, and extends for about 400 m offshore and, at the shoreward end, over 600 m alongshore. Delta growth to the north along the shore is constricted by Te Karaka Point, which effectively fixes the location of the inlet channel and sandbar, which is a factor in the consistency of the delta location. These factors result in a high-angle half-delta (Hicks and Hume, 1996). Hicks and Hume considered this type of delta shape common to the pocket-beach coasts of the Coromandel, Auckland and Northland. Sediment accumulation also occurs on the barrier side of the inlet as a flood tidal delta.

Atkin and Greer (2013) showed, by identifying morphological features, that the ebb tidal delta is significantly influenced by both the tidal regime and wave climate. Features indicative of both a wave-dominated delta (e.g. arcuate terminal lobe) and tide-dominated delta (e.g. channel margin linear bars) were both present and transient. These features indicate a mixed wave and tide-dominated coast, but no empirical evaluation (e.g. Davis and Hayes, 1984) was conducted by Atkin and Greer (2013).

Like many of New Zealand’s estuaries, the fluvially incised valley at Whangamata is in a state of infilling (Abrahamson, 1987; Woods, 2012). Estimates of sedimentation rates within the estuary range from 5 mm/yr to 11 mm/yr (Sheffield, 1991; NIWA, 1994 cited in Shand, 2008; Mead and Moores, 2004). Sheffield (1991) examined sediment samples from Whangamata estuary and inferred that fluvial sands, gravels and muds are derived from the catchment's volcanic rock and erosion of tephras in the hinterland. Marine fractions are derived from the inner shelf, and deposited during the post-glacial marine transgression (Bradshaw, 1991). Sheffield also considered the quantity of modern biogenic material noteworthy.

The estuary covers a total area of 4.3 km^2 and has an ebb tidal prism of approximately 2.7 Mm^3 (Sheffield et al., 1991). The estuary is largely intertidal, with the channel area reducing to around 0.5 km^2 at low water (Shand, 2008). Several smaller streams drain directly into the main estuarine body, however, of the ~52 km^2 catchment area the majority of watercourses feed into the Te Wairoa River (Shand, 2008), which flows through the Wentworth Valley and into the Moana Anu anu Estuary, which joins the main estuarine body ~1 km from the inlet throat.

In 1976, a 400 m long causeway spanning the Moana Anu anu Estuary, ~1 km from the confluence of the main estuarine channels, was constructed. From an examination of core samples, Sheffield et al., (1995) suggested that the construction of the causeway contributed to accelerating sedimentation rates in the Moana Anu anu Estuary.

10.2 Social and Cultural Aspects

10.2.1 Local Māori History and Traditional Use

Ngaati Whanaunga hold manawhenua status over Whangamata. They are part of a collective of tribes called Marutuuahu, named after their eponymous ancestor. They are closely related to the nearby Ngaati Hako, and also other nearby iwi of Pare Hauraki.

Ngaati Whanaunga is an independent iwi in its own right and is made up of several distinct hapuu and whaanau. The breadth and width of the tribal area is captured within the tribal saying “Mai Matakana ki Matakana” which identifies their geographical context from the tip of Matakana Island (Tauranga Harbour) in the south to Matakana (Warkworth) in the North.

Scientific evidence suggests that the first Māori people settled and cleared the Whangamata estuary area approximately 800-600 years ago (McGlone,1983; 1988; 1989). Māori populated the Coromandel Peninsula due to its abundant seafood, warm climate and long kumara (sweet potato) growing season (Sheffield *et al*, 1995).

The Ngaati Whanaunga Environment Unit is tasked with the kaitiakitanga of the tribal area on behalf of the iwi. This team seeks to protect their ancestral land, sea, waahi tapu and other taonga, from the effects of development and the many activities that take place within the rohe. Indeed, Ngaati Whanaunga are against the marina development and the mass mangove clearing occuring in Whangamata, as they believe it effects the local birds and fish (M. Baker. personal communcation, 2016).

10.2.2 Surfing and Surf Life Saving History

Whangamata Surf Life Saving Club was formed in 1949. A member of which was Peter Braun who is considered the first person to own a surfboard at Whangamata. A clear reminder of the link between SLSCs and the birth of surfing throughout many surf spots in New Zealand is that early on local SLSCs owned several boards for members to use, at Whangamata in 1961 the club had several boards available (Williamson, 2014).

By the mid-1960's young Auckland surfers had moved to Whangamata and started making surfboards (Gary Yates and Russel Wade, followed by Peter Calder and Keith McMillan), and Whangamata Boardriders was formed in 1966. In the early 1970's Bob Davies opened a surf shop on Port Road. Several notable shapers operated at the associated surfboard factory, including Bob Davies, Rodney Dalberg, Alan Byrne, Brent Munro, Paul Mitchell, Paul Shanks, Graham Gantley, Kingsley Kernovski, Warren Thompson, Mark Ogram, Wayne Lowen, Pete Anderson, and Jamie Riley. Some of these shapers have subsequently made boards for national and world champions. This pushed Whangamata into "international surf culture status and marked it as an international destination" (P. Shanks. personal communication, 2016)

Cindy Webb, who started surfing at Whangamata won the inaugural women's nationals in 1964 and 1965. Wayne Parkes, whilst originally from Takapuna, was heavily influenced by his time at Whangamata and is considered one of New Zealand's greatest competitive surfers. As of 2016, Ella Williams of Whangamata represented New Zealand in the World Surfing Leagues Qualifying Series, was the Women's World Junior Surfing Champion and won bronze at the International Surfing Associations World Championships in 2015.

Whangamata beach is generally safe for swimming and usually has small gentle waves. The islands shelter the south section of the beach from ocean swells where it is generally safer for swimming, although there are strong currents, rips and holes at the estuary entrances. During summer months the population of Whangamata swells from 3,500 to 26,000, and up to 110,000 during popular events such as Beach Hop (Is the Coast Clear? https://www.youtube.com/watch?v=4-r0Cxb2dMg). There can be strong rips/currents, and sudden drop-offs and holes. In the 10 years from 2005 to 2015, 412 rescues occurred on Whangamata Beach with rips/holes being identified as a causal factor in 37.9% of these rescues[8]. Whangamata is a patrolled beach from October to April at the weekends and every day during parts of the summer.

[8] Rescue statistics from the Surf Life Saving New Zealand's Patrols and Memberships database (PAM) for the ten years from 1 July 2005 to 30 June 2015.

10.3 Surf Break Characteristics

Surf breaks occur all along Whangamata Beach, this project is concerned with Whangamata Bar, or simply “The Bar”. The wave attributes its breaking qualities to the ebb tidal delta, it is classified as an estuary bar break (Mead, 2000) or river/estuary entrance bar (Scarfe et al., 2009a).

Waves approach the bar and the terminal lobe (most seaward extension) of the ebb tidal delta focusses wave through refraction to form a defined peak (Scarfe et al., 2009 a, b; Atkin and Greer, 2013). Mead and Black (2001b) identified Whangamata as having both ramp (offshore) and wedge components that produce moderate to steep faces with slow to moderate peel speed; with fast sections. From the peak, waves peel down the seaward flank or wedge component of the bar.

The wave is steep and hollow ideal for high-performance surfing (Moorse and Brunskill, 2004). Mead and Black (2001c) estimated vortex ratios of 2.90 to 2.95, giving a medium breaking intensity.

At other times the terminal lobe gets cut by rip channels which causes the waves to reform cutting the length of the ride and therefore compromising the quality of the surf break.

While The Bar is predominantly known for producing a long left-hand wave, a right-hander also breaks from the peak toward the tidal inlet channel. Being a sand bottom break, and a very dynamic morphological feature (influenced by strong tidal currents and waves), wave quality is not just a function of the incident waves, but also of changes in the shape of the ebb tidal delta sand body.

Atkin and Greer (2013) used output from a Boussinesq wave model to examine wave peel angles for 14 different morphological states at Whangamata ebb tidal delta. The results showed that surfability is particularly sensitive to the terminal lobe, the curvature of the deltas southern margin and the marginal flood tide channel positions. It was hypothesised that the wave climate prior to bathymetric surveys had a significant effect on ebb tidal delta morphology, and ultimately the wave breaking pattern associated with the ebb tidal delta.

10.4 Current and Potential Threats

There is ongoing debate as to whether the quality of the surf break has been compromised by anthropogenic activities, in particular, the development of the marina inside the estuary and the associated maintenance program. Unfortunately, there are insufficient data to determine cause and effect and the studies undertaken before and after the granting of resource consent

(Shand, 2008; Pearce, 2013) provide little useful information with respect to actual impacts, cause and effect (if indeed, there has been any change).

Construction of the marina began in September 2008 and was completed by October 2009. The marina is located directly downstream from the causeway on the southeastern bank to the entrance of the Moana Anu anu Estuary. The marina consists of breakwaters surrounding a dredged basin formed from the removal of 165,000 m^3 of material. The area of the basin is 0.04 km^2 and 0.014 km^2 of the salt marsh was reclaimed during construction. The marina entrance flows directly into the main Moana Anu anu Estuary channel. Access to the marina along the channel required dredging of approximately 32,000 m^3 of material. Periodic maintenance dredging is employed to ensure the channel retains a depth of ~1.5 m below the Lowest Astronomical Tide.

Concerning the impacts of dredging in the estuary (both development and maintenance), and while there are morphological differences in the bar's overall shape pre and post-marina development (Atkin and Greer, 2013), there is no evidence to determine whether these differences are natural or in any way connected to the marina development.

In 2012 the Surfbreak Protection Society (SPS) presented a report to the Hauraki Gulf Forum (SPS, 2012) which triggered a review of the maintenance dredging consents. The review was considered both inconclusive and incomplete by SPS. In response, SPS initiated a 4-year photographic study from 2013-2017 which they believe shows a direct link between dredging activity and morphological change at the tidal inlet throat. SPS also consider the natural sediment transport was altered when the dune system was filled and stabilised with planting (P. Shanks. personal communication, 2016).

Further concerns raised during stakeholder consultation include wastewater treatment practice by the council with reports, submissions to council plans and appeals to the Environment Court of spills and leakage of waste from aeration ponds and spray fields into the Whangamata Estuary; stormwater discharge near the surf breaks; and clear felling of forestry in the Whangamata Estuary catchment. It is also noted that in response to an SPS submission on the Natural Character designation by Thames-Coromandel District Council, an area designated as having Natural Character will only consider those features above Mean High Water Spring (MHWS).

10.5 Summary

Whangamata is a popular surf break that is situated on the ebb tidal delta of the Whangamata Estuary. As such, it varies a lot due to changes in the exchange of water and sediment to and from the estuary, along with shadowing provided by the headland. The main perceived threats are associated with development within the township, such as the construction of the marina, and the ongoing need for maintaining the channel for boating; and water quality issues.

11 Whareakeake

Located some 5 km northwest along the coast from the entrance to Port Otago (Figure 11.1), is Whareakeake, also called “Murderers”, or “Murdering Bay”. Offshore from Whareakeake is a dredge spoil disposal site known as Heyward’s, which has been in operation for over a century. Whareakeake is one of the 17 Nationally Significant Surf Breaks.

Figure 11.1: Whareakeake (source Land Information NZ, orthophoto archive, 2004-11).

11.1 Environmental Setting

Whareakeake is 550 m long, approximately north by east facing, sandy beach between Pilot Point to the west and Purehurehu Point to the east. The beach is the seaward edge of a short

(~2 km) and narrow valley that drains into a limited backdune wetland. The unnamed stream formed through the valley discharges onto the beach at the eastern end. Single (2105) states that the beach is in a state of dynamic equilibrium, based on observations of prolonged erosion but determining a positive long-term rate of shoreline change from 1979 of 1.3 myr^{-1}.

Pilot and Purehurehu Points extend approximately 200 and 600 m offshore from the beach, respectively. The compartmentalisation of this stretch of coast by the extended points results in a pocket beach style beach, analogous to those seen on the Coromandel Peninsular, like Whangamata, where longshore sediment transport, or rather a transfer of material from one sediment cell or compartment to another is very limited. Background geology is similar to the adjacent Aramoana (see Section 5.1).

11.2 Social and Cultural Aspects

11.2.1 Local Māori History and Traditional Use

Kāti Huirapa of Kai Tahu, are the local iwi who hold Manawhenua status over Whareakeake. Formerly known as Murderers beach, The New Zealand Geographic Board in consultation with local iwi, Ngai Tahu, changed it back to the original Māori name, Whareakeake.

The name Murderers refers to an incident that occurred in 1817. There are numerous versions of this incident. One such version is provided by Te Paro, a chief of Murihiku in Southland. Te Paro describes how some Europeans took a local chief (Korako) and others captive aboard their ship following the murder of a fellow European (McFarlane, 1939). In preparation to rescue Korako from the ship, the local Māori wove toi-toi leaves into a thick pokeka (rough raincoats) to help protect them from the European guns. They retrieved Korako and returned back to land in their canoes, none of those on the canoe were killed due to their pokeka (McFarlane, 1939).

A European account was provided by the master of the vessel, Captain James Kelly. After attempting to barter for potatoes in a village at Whareakeake, Kelly and six of his men were unexpectedly attacked and three were killed. As Kelly and his remaining men arrived back at their ship, 150 local Māori were on board awaiting them. A fight ensued, and Kelly's men were successful in capturing the chief, Karaka. The following day, Karaka's men returned to the ship to recapture him. They were successful, however he died the following day. At the time it was uncertain why Kelly and his men were attacked. It was later ascertained that one of Kelly's men had, in 1811, stolen a preserved head from local Māori at Riverton (McFarlane, 1939). He had then sailed to Sydney before the theft was discovered. Incidentally this was the first baked head offered for sale in Sydney (McFarlane, 1939). As such, the attack by local Māori on Kelly and his men was utu, or revenge for the previous indiscretion.

In the past, numerous finished and unfinished greenstone implements had been found on this beach. According to local Māori, Whareakeake was a popular greenstone manufacturing centre in pre-European times (McFarlane, 1939). Further back in time, archaeological evidence shows that Whareakeake was also a Moa hunting site (Potiki, 2011). Nowadays it is farm land, most often only frequented for the surf.

There are numerous areas nearby of cultural significance. These include the once impregnable Māoutahi pā, Aramoana, and Taiaroa headland where the famous Otākou Marae stands.

Kāi Tahu ki Otago Ltd (KTKO Ltd) is the local organisation who focus on of environmental health. Representing the surrounding rūnaka of Otago - Te Rūnanga o Moeraki, Kāti Huirapa Rūnaka ki Puketeraki, Te Rūnanga o Ōtākou and Hokonui Rūnanga , KTKO Ltd are working closely alongside Port Otago in regards to the port dredging, with Rūnaka members on each of the port dredging boards. The Rūnaka are supportive of the dredging, subject to various conditions, such as improving the monitoring (N. Karaitiana, personal communication, 13th May 2016). The Rūnaka see the benefits as economical and employment opportunities for their people (N. Karaitiana, personal communication, 13th May 2016). Kāti Huirapa does not oppose the dredging of the Otago Harbour in principle but does have grave concerns about the proposed spoil deposition, its potential effects on the inshore rocky reefs, and the current monitoring conditions.

11.2.2 Surfing and Surf Life Saving History

Surfing history at Whareakeake is not documented, but likely to be the same as the history at Aramoana (see section 5.2.2). In terms of surf lifesaving, Whareakeake can be hazardous to water users as it receives large swell from a range of bearings. The beach is bound by headlands, along which strong rip currents flow out to sea, particularly at times of higher wave energy. Rip currents and inshore holes can also form anywhere along the beach. Inexperienced water users are at high risk of being overcome by large waves, stepping or being washed into inshore holes and channels, and being swept out to sea by rip currents. The site can be accessed via Murdering Beach Road; there is a small area for car parking, but no other facilities. There is no surf lifeguarding service at the site. There are no recorded rescues at the site.

11.3 Surf Break Characteristics

Moorse and Brunskill (2004) describe Whareakeake as a high-quality right point break that breaks adjacent to Purehurehu Point producing very long peeling waves, with steep, long walls and hollow sections. This is consistent with the description of a wave with a Medium/High breaking intensity (Mead and Black, 2001c; Figure 11.2).

Changing sand banks along this headland (partially caused by sand moving shoreward from the dredge spoil mound) result in variability in the quality of the offshore section. The stream at the southwestern end may also influence the beach morphology and the surfing conditions.

When conditions are appropriate for waves to initiate breaking on the outer reef of Purehurehu Point, surfers can experience rides the entire length of the headland to the beach, which is approximately 600 m. Beyond this potential ride length, there is no information regarding the surfing wave quality at this break. No satellite or aerial imagery is currently available to extract peel angles from waves at Whareakeake.

Figure 11.2: Hollow, plunging wave at Whareakeake (image courtesy of Rowan Klevstul).

11.4 Current and Potential Threats

Like Aramoana, the surf break at Whareakeake has been impacted by dredge disposal at the Heyward site offshore, so management of the break is an ongoing requirement. Due to the amount of time that the Heyward dumpsite has been used, there are uncertainties with respect to the original nature of the Whareakeake site (there is some suggestion that a reef existed in this area), and how the disposal site influences the break at Whareakeake. Given the sheltered nature of Whareakeake, wave focussing on the Heyward mound is likely to have a beneficial impact on the break by increasing wave height. However, the same mechanism (i.e. wave focussing) has the potential to direct wave energy away from Whareakeake; the direction of the focussing is dependent on the shape of the Heyward disposal mound (Weppe et al., 2013).

During the temporary resource consent (see Section 5.4), numerical modelling studies of the effects of the mound helped to determine how the orientation and shape of the disposal mound impacted waves at Whareakeake. This has led to a large increase in the size of the disposal ground to enable better management in terms of mound orientation and mound height, which have been incorporated into the conditions of the current resource consent application. Continued monitoring (using a remote camera) will be required to continue to ensure that the management of the morphology of the Heyward disposal mound does not negatively impact Whareakeake. It is thought that the movement of sand shoreward from the dredge spoil changes the conditions of surfing waves along the headland to the east.

11.5 Summary

Whareakeake is probably the least well-known of the breaks that we explored in our stakeholder meetings. It is more difficult to access, and further from developed areas. Nevertheless, consultation indicated it had significance to both surfers and iwi living in the region, and the main perceived threats were associated with the dumping of dredge spoil and its effect on the preconditioning of waves.

12 Report Summary

This Initial Assessment report summarises the state of knowledge around the 7 surf breaks that form the basis of this project. Consistent themes from the investigation are that the breaks lack baseline monitoring data from which to base a quantitative understanding of the factors that control the quality of breaks. Considerable qualitative data and local knowledge have been collected from the stakeholder meetings/hui, stakeholder surveys, web material, and existing literature, along with evidence prepared for various historical court hearings surrounding the breaks.

Key perceived anthropogenic threats appear to be development (the marina in Whangamata, the Port of Otago dredge spoil disposal, the Manu Bay boat ramp, and the proposed airport extension and ongoing maintenance works at Lyall Bay), water quality and increased surfer numbers. Natural threats were particularly evident on the sandy sites such as Piha, Aramoana and Wainui, where changes to sediment drift patterns and surf-zone currents changed the quality of the break from time to time. Differentiating the natural effects from the anthropogenic effects was a common theme. The assessment to date has shown that the existence and quality of the surf breaks at all of these sites form an essential part of the local culture and society, both for Māori and non-Māori as well as for visitor and tourist experience. This re-enforces the vital essence of the importance of this body of research work to New Zealand and its people.

The next phase of the overall project is to install monitoring cameras at all of the sites except Aramoana and Whareakeake where the Port of Otago already has monitoring in place. Data from the cameras will provide information on the surfing quality and how it relates to wave conditions and the geomorphology at each site. These data will inform the development of guidelines which are an outcome of the project.

13 Acknowledgements

We thank all the people who generously provided their advice and opinions during stakeholder workshops and took the time to fill in our survey. We also thank local iwi from around our sites who were able to provide their unique perspectives in such an open and friendly way. These include, but are not limited to;

- Te Kawerau a Maki
- Ngāti Whanaunga
- Ngāti Haako
- Ngaati Hounuku/Te Paetoka
- Tainui Awhiro
- Ngāti Oneone
- Ngāti Rakaiatane
- Ngāti Awa
- Te Atiawa
- Ngāti Toa Rangatira
- Kati Huirapa
- Kai Tahu
-

We thank Nick Mulcahy for providing water safety-related information and rescue statistics for the seven study sites. Thanks to the project's steering committee, which includes representation from Auckland Regional Council, Department of Conservation, Landcare Research - Manaaki Whenua, Lincoln University, Surfbreak Protection Society, Surf Life Saving New Zealand, and Waikato Regional Council.

14 References

Abrahamson, L., 1987. Aspects of Late Quaternary Stratigraphic and Evolution on the Coromandel Peninsula - New Zealand. Unpublished M.Sc. Thesis, Hamilton, New Zealand: University of Waikato, 250p.

Atkin, E.A. and Greer, D., 2013. Analysis of Bathymetric Surveys, Wave Climate, Breaking Patterns and Wave Driven Circulation at Whangamata Ebb Tidal Delta. eCoast Marine Consulting and Research Technical Report, prepared for Waikato Regional Council.

Atkin, E. A. and Mead. S. T., 2016. Regionally Significant Surf Breaks in the Waikato Region. eCoast technical report for Greater Wellington Regional Council.

Atkin, E. A., Gunson, M. and Mead. S. T., 2015. Regionally Significant Surf breaks in the Greater Wellington Region. eCoast technical report for Greater Wellington Regional Council.

Battjes, J. A., 1974. Surf Similarity. Proc. 14th Coastal Engineering Conference. ACSE p.466-480.

Bradshaw, B.E., 1991. Nearshore and Inner Shelf Sedimentation on the East Coromandel Coast, New Zealand. Unpublished Ph.D. Dissertation, Hamilton, New Zealand: University of Waikato, 544p.

Brathwaite, R.L, 1990. Ironsand resources of the west coast North Island. Unpublished contract report no. 1990/5 for Electricorp, DSIR Geology & Geophysics.

Carter, L. and Lewis, K. 1985. Variability of the modern sand cover on a tide and storm driven inner shelf, south Wellington, New Zealand. New Zealand journal of Geology and Geophysics 38: 451-470.

Clapham., G., 2016a. A Surfing Way of Life: An exploration of the surf culture that defines the beaches of Wainui and Makorori. [online] Available at: http://www.wainuibeach.co.nz/archive1thesurfi.html

Clapham., G., 2016b. Wainui Beach Surf Breaks [online] Available at: http://www.wainuibeach.co.nz/WAINUI%20INFO/surfingwainuiand.html

Coney, S., 2016a. History of Piha Surf Life Saving Club. [online] Accessible at: http://www.piha.co.nz/maori-settlement-at-piha/

Coney, S., 2016b. Maori settlement at Piha. [online] Accessible at: http://www.piha.co.nz/history-of-piha-surf-life-saving-club/

Department of Conservation, 2010. New Zealand Coastal Policy Statement 2010. Wellington: Department of Conservation.

Dahm, J. and Munro, A., 2002. Coromandel Beaches: Coastal Hazards and Development Setback Recommendations. Environment Waikato Technical Report No. 02/06.

Dunn, A., 2013. Wainui Beach Management Strategy (WBMS) - Surf Break Protection. Eco-I technical report for Gisborne District Council.

Galvin, C., 1968. Breaker Type Classification on Three Laboratory Beaches. Journal of Geophysical Research, Volume 73, pp. 3651-3659.

Gisborne District Council, 2008. W. D. Lysnar and Wainui Beach Reserves Management Plan. [Online] Available at: http://www.gdc.govt.nz/w-d-lysnar-and-wainui-beach/ Accessed retrieved 30th September, 2016.

Gisborne District Council (2014). Wainui Beach erosion management strategy. Gisborne District Council Report. August 2014. 44p.

Greensill, A. & Ellison, S. (2010). *Tainui o Tainui ki Whaingaroa Submission*. Submission to the committee regarding the Marine and Coastal Area (Takutai Moana) Bill 2010. https://www.parliament.nz/resource/0000139405

Hicks, D. M. and Hume, T. M., 1996. Morphology and Size of Ebb Tidal Deltas at Natural Inlets on Open-Sea and Pocket Bay Coasts, North Island, New Zealand. Journal of Coastal Research, Volume 12, pp. 47 - 63.

Hume, T.M. and Herdendorf, C.E., 1993. On the Use of Empirical Stability Relationships for Characterising Estuaries. Journal of Coastal Research. 9(2) pp 413-422.

Hume, T.M., Smith, R.K., Ray, D.,1999. Piha Beach: Coastal physical processes, effects of human activities and future management. *NIWA Client Report* WTK90201/1: 48.

Hutt, J. A., Black, K. P. and Mead, S. T., 2001. Classification of Surf Breaks in Relation to Surfing Skill. Journal of Coastal Research, Issue Special Issue No. 29, pp. 66-81.

Iribarren, C. R. and Nogales, C., 1949. Protection des Ports, XVIIth International Navigation Congress. pp. 31-80.

Kilpatrick, D., 2005. Determining Surfing Break Components at Aramoana Beach, Dunedin. Dunedin, New Zealand: The University of Otago, Honours dissertation, 68p, appendixes.

King, D., Hume, T., Nichol, S., 2005. Rapid shoreline building on a stormy coast. Water and Atmosphere 13: 14-15.

King, D., Nichol, S., Hume, T., 2006. Rapid onshore sand flux in a high wave energy littoral cell, Piha Beach New Zealand. Journal of Coastal Research, 22(6): 1360–1369.

Knox, W., 2016. Personal communication, 1st April 2016.

Love, M., 2016. Personal communication, 11th March 2016.

McFarlane, R., 1939. The Story of Murdering Beach: A Pakeha-Maori Encounter Near Dunedin in 1817. The New Zealand Railways Magazine, Volume 14, Issue 8. Wellington, New Zealand: New Zealand Government Railways Department.

McGlone, M.S., 1983. Polynesian deforestation of New Zealand: A preliminary synthesis. Archaeology in Oceania, 18, 11-25.

McGlone, M.S., 1988. Report on the pollen analysis of estuarine cores from Whangapoua and Whitianga Harbours, Coromandel Peninsula. DSIR Botany Division Report 648.

McGlone, M.S., 1989. Report on the pollen analysis of estuarine cores from the Firth of Thames. DSIR Botany Division Report (March 1989).

McKenzie, L. 2014a. Surf Survey Summary report, August 2013 - September 2014, Port Otago Limited internal report. [Online]. Available at: https://www.portotago.co.nz/assets/Uploads/InshoreDredgingConsultation/Surf-Survey-Summary-Report-1-August-13-September-14.pdf

McKenzie, L. 2014b. Surf Survey Summary report, September 2014 - May2015, Port Otago Limited internal report. [Online]. Available at: https://www.portotago.co.nz/assets/Uploads/InshoreDredgingConsultation/Surf-Survey-Summary-Report-2-ASeptember-14-May-2015.pdf

Mead, S. T., 2000. Incorporating High-Quality Surfing Breaks into Multi-Purpose Reefs. Doctor of Philosophy in Coastal Oceanography and Surfing Reefs thesis. University of Waikato. Pp 209 + appendices.

Mead, S. T., 2013. Potential Effects of Trans-Tasman Resources Mining Operations on Surfing Breaks in the Southern Taranaki Bight. Report prepared for NIWA, October 2013.

Mead, S. T., 2016. Personal Communication

Mead, S. T. and Black, K. P., 2001b. Functional Component Configurations Controlling Surfing Wave Quality at World-Class Surfing Breaks. Journal of Coastal Research, Issue Special Issue No. 29, pp. 2-32.

Mead S. T. and Black, K. P., 2001c. Predicting the Breaking Intensity of Surfing waves. Journal of Coastal Research, Issue Special Issue No. 29.

Mead, S. T., and A. Moores, 2004. Estuary Sedimentation: A Review of Estuarine Sedimentation in the Waikato Region. ASR Ltd report prepared for Environment Waikato.

Mead, S., Atkin, E. and Phillips, D., 2011. Literature Review and a Preliminary Investigation of Offshore Focussing Multi-Purpose Reefs. eCoast technical report prepared for Unitec.

Meade, D., 2014. Gisborne Boardriders Club inc – A Look Back Over The Last 50 Years. [video]. Available at: http://nzsurfmag.co.nz/gisborne-boardriders-club-inc-a-look-back-over-the-last-50-years/

Monks., N. 2014. Piha Surf Waitangi Day 2014. [online] Available at: https://www.youtube.com/watch?v=oQEZGqjjQA8

Moorse and Brunskill, 2004. Wavetrack New Zealand Surfing Guide. Greenroom Surf Media Ltd, Mount Maunganui.

Mortensen, S., M. Tree and B. Tuckey, 2015. Wellington Airport Runway Extension Surf Break Impact Assessment. Numerical Modelling. Preliminary mitigation investigations and feasibility study. Prepared for Wellington International Airport Ltd, August 2015

NIWA, 2015. Wellington International Airport Runway Extension: Coastal Processes Assessment. Prepared for Wellington International Airport Ltd, August 2015

Pearce, G., 2013. Whangamata Ebb Tidal Bar, Monitoring Report. Tonkin and Taylor report prepared for Whangamata Marina Society.

Phillips, D. J., 2004. Sediment Dynamics of a Shallow Exposed Surfing Headland. Unpublished PhD Thesis. University of Waikato. 269 p.

Piha Surf School, 2014. Piha Beach New Zealand Autumn Surfing. [online] Available at: https://www.youtube.com/watch?v=6o_VefNdINs

Pickrill, R. A., & Mitchell, J. S., 1979. Ocean wave characteristics around New Zealand, New Zealand Journal of Marine and Freshwater Research.

POL, 2016. Port Otago Limited Application RM10.193. [online] Available at: http://www.orc.govt.nz/Information-and-Services/Resource-Consents/Notified-Applications/Archived-Resource-Consents/Port-Otago-Limited-Application---RM10193/

Potiki, T., 2011. Statement of Evidence of Tahu Potiki on behalf of Te Runanga o Ōtākou. In the matter of an application for resource consents for Project Next Generation by Port Otago Limited. [online]. Available at: http://www.orc.govt.nz/Documents/Content/Information%20Services/Resource%20Co nsent/Port%20Otago/Evidence/Submission%20-%20Evidence%20of%20Tahu%20Potiki%20-%2012%20Apr%2011.pdf

Puriri, K., 2015a. Surf Into Summer: Butch Walters. Raglan Chronicle, [online]. Available at: http://www.raglan.net.nz/2015/12/surf-into-summer-butch-walters/

Puriri, K., 2015b. Surf Into Summer: The Point. Raglan Chronicle, [online]. Available at: http://www.raglan.net.nz/2015/12/surf-into-summer-the-point/

Puriri, K., 2016. Surf Into Summer: Malibu Hamilton. Raglan Chronicle, [online]. Available at: http://www.raglan.net.nz/2016/03/surf-into-summer-malibu-hamilton/

Rei, M., 2016. Personal communication, 8th March 2016.

Rust, R., 2016. Personal Communication.

Scarfe, B., 2002. Categorising Surfing Manoeuvres using Wave and Reef Characteristics. Hamilton, New Zealand: University of Waikato, Master's thesis, 181p.

Scarfe, B., 2008. Detailed Monitoring of the Morphodynamic Response of a Beach to an Artifical Surfing Reef at Mount Maunganui, New Zealand. Unpublished Doctoral Thesis, Waikato University.

Scarfe, B. E., Healy, T. R., Rennie, H. G., & Mead, S. T., 2009a. Sustainable management of surfing breaks: an overview. Reef Journal, 1(1), 44–73.

Scarfe, B. E., Healy, T. R., Rennie, H. G., & Mead, S. T., 2009b. Sustainable Management of Surfing Breaks: Case Studies and Recommendations. Journal of Coastal Research, 25(3), 684–703.

Searancke. N., 2016. Personal Communication, 14th May 2016.

Shand, T., 2008. Whangamata Marina Numerical Model Development and Reporting. Tonkin and Taylor report prepared for Whangamata Marina Society.

Shanks, P., 2016. Personal Communication.

Sheffield, A.T., 1991 The Sedimentology and Hydrodynamics of Whangamata Harbour. Unpublished M.Sc. Thesis, Hamilton, New Zealand: University of Waikato, 180p.

Sheffield, A.T., Healy, T.R. and de Lange, W., 1991. Aspects of Tidal Inlet Stability at Whangamata Harbour, New Zealand. Coastal Engineering Climate for Change: 10th Australasian Conference on Coastal and Ocean Engineering, Auckland, New Zealand

Sheffield, A.T., Healy, T.R. and McGlone, M.S., 1995. Infilling Rates of a Steepland Catchment Estuary, Whangamata, New Zealand. Journal of Coastal Research, 11(4), pp. 1294 - 1308.

Single, M., 2015. Long-term shoreline change analysis, Otago Harbour entrance to Karitane, Shore Processes and Management Ltd technical report prepared for Port of Otago Ltd

SPS, 2012. The SPS Whangamata Bar Report. Surfbreak Protection Society, [online]. Available at: http://www.surfbreak.org.nz/wp-content/uploads/2012/08/The_SPS_Whangamata_Bar_Report_small-printable-2.pdf

Surf Life Saving New Zealand, 2016. *Patrols and Memberships database*. Surf Life Saving New Zealand, Wellington, New Zealand. Retrieved from: https://webportal.surflifesaving.org.nz/

Taua, T., 2009. He kohikohinga kōrero mō Hikurangi. In MacDonald, F., & Kerr, R. (eds) (2009). West: The history of Waitakere. New Zealand: Random House Ltd.

TCDC, 2016. Northern Whangamata Harbour Coastline. Thames-Coromandel District Council, Natural Character Assessment – Units: Unit 80 – Sheet 89

The Gisborne Herald, 2014. Tow-in Surfing Pines Gisborne 8th March 2014. [video]. Available at https://www.youtube.com/watch?v=UjCYda--uf8

Tupara, N., 2016. Personal Communication, 21st April 2016.

Turei, P. 2011. Here's lurking at you kid. Retrieved from http://www.nzherald.co.nz/aucklander/news/article.cfm?c_id=1503378&objectid=11034781

Walker, J. R., 1974a. Recreational Surf Parameters. University of Hawaii, Department of Ocean Engineering. Honolulu: LOOK Laboratory.

Walker, J. R., 1974b. Wave Transformations Over a Sloping Bottom and Over a Three-Dimensional Shoal, PhD Thesis, University of Hawaii.

Weppe, S., McComb, P., Johnson, D., Coe,L. and Beamsley, 2013. Numerical study of wave and sediment dynamics at dredge disposal sites near the Otago Harbour Entrance, New Zealand. Proceedings of the Australasian Coasts and Ports Conference, 2013.

Whittaker, J., 2016. Personal Communication

Williamson, L., 2012. Gone Surfing: the Golden Years of Surfing in New Zealand 1950-1970. 1st ed. [E-pub] Warkworth: Halcyon Design Ltd.

Woods, J.L.D., 2012. The Evolution of a Holocene Estuarine Barrier on the Coromandel Coast, New Zealand. Geographical Research, 50 (1), p89–101.

Wright, L.D and Short, A.D, 1984. Morphodynamic Variability of Surf Zones and Beaches: A Synthesis. Marine Geology, 56, p.93–118.

Appendix A. Surfing and Surf Break Terminology

Lip – the lip is the breaking crest of the wave.

Barrel/Tube – when a wave breaks and a hollow space is created between the breaking lip and the wave face this is referred to by surfers as a barrel or tube. One of the most highly regarded manoeuvres in surfing is to ride inside the barrel or tube. When a wave is described as being hollow it provides the opportunity to get barrelled or "tubed". Alternatively, if the wave is steep but not barrelling it may be described as "walled up".

Offshore wind –wind direction and strength is a very important factor with respect to surfing wave quality. Typically, light local winds provide ideal surfing conditions. Offshore winds, that is a direction heading out to sea, perpendicular to wave crests, can 'clean' waves faces making for improved surfing conditions, the direction of offshore wind, which is always stated as direction coming from (e.g. southerly), is considered the optimum wind condition. It should be noted that preferred wind direction is as subjective as surfing wave quality and comes down to participant choice.

Peak – the highest part of the wave, which breaks first and so is also known as the take-off. Wandering or shifting peaks means that there is no defined take-off zone, and the surfer may be required to paddle towards peaks to take-off in the right spot. A w**edging peak** indicate a peak that is particular pronounced.

Peel – surfers require a clean unbroken wave face for performing surfing manoeuvres. In order to ride the wave for as long as possible, the wave must peel where the breaking part of the wave crest translates laterally across the face of the wave. This is opposed to a wave that breaks simultaneously along its length, which is referred to as a **'close-out'**.

A Left – a wave peeling from right to left as viewed by a person facing the shore. Also referred to as a **"Left hander".**

A Right – a wave peeling from left to right as viewed by a person facing the shore. Also referred to as a **"Right hander".**

A-Frame – a wave that peels both left and right from the same peak.

Surfable wave – a wave that can be caught and ridden by a surfer. Surfable waves have a wave breaking point that peels along the unbroken wave crest so that the surfer is propelled laterally along the unbroken face of the wave.

Swell corridor – the region offshore of a surf break where ocean swell travels and transforms to a surfable wave.

Appendix B. Study Site Decision Matrix

	Access	Infrastructure	Sensitivity	Threats	Usage	Dependent Population	Effectiveness of Methods	SLSNZ Availability	Total
Whangamata Bar	5	5	5	5	4	3	5	1	**33**
Manu Bay	5	5	3	4	5	5	5	0	**32**
Lyall Bay	5	5	4	5	4	5	3	1	**32**
Whale Bay	5	5	3	3	5	5	5	0	**31**
Piha	5	5	4	3	4	5	3	1	**30**
Wainui Beach	5	5	5	3	3	4	3	1	**29**
Karitane	4	4	5	5	3	3	4	0	**28**
Main Beach	5	5	4	3	4	3	3	1	**28**
Fitzroy	5	5	4	4	3	3	2	1	**27**
Whareakeake	3	1	5	5	4	4	5	0	**27**
Waiwhakaiho	4	2	4	4	5	3	4	0	**26**
The Spit (Aramoana)	5	2	5	5	2	4	3	0	**26**
Indicators	3	2	3	2	5	5	5	0	**25**
Mangamaunu	5	2	2	2	4	5	5	0	**25**
Makorori Point/Centres	4	1	5	3	4	4	3	0	**24**
Meatworks	5	2	2	2	5	5	3	0	**24**
Stent Road	4	2	2	2	5	3	5	0	**23**
Shipwreck Bay	2	2	5	4	2	2	4	0	**21**
Matakana Island	2	1	5	5	2	2	2	0	**19**
The Island	1	1	3	4	3	1	4	0	**17**
Papatowai	1	1	2	1	1	1	5	0	**12**

Appendix E. Advances in Research and Management of Surfing Resources

Advances in research and management of surfing resources

Ed Atkin, eCoast

Aotearoa New Zealand is a world leader in the management of surf breaks and has been at the forefront of surf science research since the mid-1990s. The nation's leadership in applied and effective surfing resource management is the envy of many surfing countries worldwide. It is the pairing of extensive research efforts, such as the University of Waikato/NIWA Artificial Reef Program (ARP, established in 1995) and the plethora of ensuing studies, with ground-breaking legislation in the Resource Management Act and New Zealand Coastal Policy Statement 2010 to recognise unique and finite coastal characteristics, that lead to this venerable position.

In late 2015, a research group lead by the University of Waikato received Ministry for Business, Innovation and Employment (MBIE) Targeted Research funding (see *Coastal News* Issue 67) to consider the nation's current position of applied and effective surfing resource management. A primary driver of the project was to address the lack of data and understanding of surf breaks needed to enable informed decision making by council staff, engineers, and consultants about activities in the coastal environment, with the aim of establishing clear, quantitative measures and guidelines describing the characteristics of surfing resources. The project undertook stakeholder engagement meetings, surveys, intensive fieldwork, and deployed monitoring systems. The research project culminated in the publication of scientific journal articles (Bryan and Atkin, 2019) and the *Management guidelines for surfing resources* (Atkin et al., 2019), which have since been endorsed by the Department of Conservation.

Beyond the ARP, subsequent MSc and PhD studies, and the MBIE project, since 2012 the regions of Northland, Auckland, Waikato, Taranaki, Greater Wellington and Southland have all identified Surf Breaks of Regional Significance (SBRS). Canterbury is currently in the process of public consultation. Moreover, Waikato, Greater Wellington and Southland have all delineated swell corridors for the identified SBRS. There have been detailed studies that consider complex characteristics of Surf Breaks of National and Regional Significance, and numerous consent hearings concerning the integrity of surf breaks (see Mead and Atkin, 2019; Weppe and Shand, 2019; and references therein). These significant efforts are a testament to the value Aotearoa New Zealand places on surfing resources.

However, with each potential threat to surf break integrity or episode of mismanagement, both at home and overseas, there are new learnings and surfing research is continually evolving. With a view to giving permanency to the efforts of the MBIE funded research project, a not-for-profit charitable trust was established, the Aotearoa New Zealand Association for Surfing Research (ANZASR). The ANZASR took responsibility for the camera systems, associated data base and *Management guidelines for surfing resources*. The overriding vision of the ANZASR is to help keep Aotearoa New Zealand at the forefront of surfing resource management. To this end, the ANZASR aims to:

- Educate the current and next generation on sustainable management, surfing resource management and surf science.
- Undertake reviews and updates of the *Management guidelines for surfing resources* to keep them relevant to the latest research.
- Establish surf break research goals that will benefit Aotearoa New Zealand, by:
  - providing a centralised, supportive body to aid in research funding applications;
  - funding and guiding student research projects.
- Promote the sharing of surf break research data and learnings to an international audience to aid global efforts to manage surfing resources.
- Engage with and educate local authorities about surfing resource management.
- Host, maintain and establish new surf break monitoring systems across Aotearoa New Zealand.

The use of cameras systems to monitor the coastal environment is well established both overseas and in New Zealand since 1997; they collect repeatable, high frequency data that is ideally suited to monitoring breaking waves. The georectification of oblique photogrammetry opens the capacity for spatial quantitative analysis. The camera systems set up as part of the MBIE project were done so to monitor South Piha (Auckland), Waikeri (Manu Bay; Raglan, Waikato), Whangamata (Coromandel Peninsula, Waikato; Figure 1), Wainui Beach (Gisborne) and Lyall Bay (Wellington), with camera data supplied from Aramoana and Whareakeake (Otago) by the Port of Otago.

While several efforts have focussed on monitoring surf breaks with camera systems, none have effectively recorded fundamental surfing wave quality characteristics in an automated and quantitative matter. Peel angle is the angle between the trail of broken white water and the crest of the unbroken part of the wave (Walker et al., 1972). Peel angle indicates the rate that the breaking part of the wave translates laterally. Early efforts to monitor a Multi-Purpose Reef in Boscombe, UK with oblique photogrammetry and derive peel angle from georectified imagery yielded meaningful results (Atkin, 2010). However, the overhead of field data collection and manual annotation of geo-rectified images make the approach unfeasible long-term. During the MBIE research project an automated system was developed to measure peel angles from geo-rectified images (McIntosh, et al., 2018). This system yielded comparable results to manual annotation and measurement approaches.

Figure 1: Camera monitoring system at Whangamata, Waikato.

However, the system was computationally intensive and relied on parameterising pixel intensity gradient thresholds – it still required manual input. More recent work has managed to track the breaking area of the wave (Thompson et al., 2021), but fails to capture both the fundamental components required for measuring peel angle – the unbroken wave crest and point of instantaneous breaking.

The first project under the ANZASR banner was to develop a methodology for efficiently documenting surfing wave quality characteristics. Given the core database of images, Machine Learning (ML) object detection was considered an applicable approach, and early investigations in the application of ML during the MBIE project yielded promising results.

Development of an effective methodology and application are now described in detailed research papers (Atkin, 2021; Atkin et al., 2021). In summary, a convolutional neural network object detection model (Jocher et al., 2020) was trained with a pool of 2000 randomly selected images from the remote monitoring system at Waikeri (Manu Bay, Raglan). Leveraging both oblique and orthorectified images, along with spatially restrictive annotation tools, all instances of surfable breaking waves in each image were annotated with breakpoint and crest locations. Training included more than 60 training runs that considered different combinations of annotations and model settings to maximize the accuracy for this application. By virtue of not being able to annotate surfable waves on some images during labelling, training of the model has effectively incorporated a surfability threshold Artificial Intelligence.

The trained model was used to analyse ~1 million images taken at midday between May 2017 and June 2020 from the Waikeri system. Object detection on a low-end graphics processing unit takes <20 ms/image. In this subset more than 750,000 objects were detected. A wave tracking algorithm was then used to isolate 117,540 individual peeling waves (consecutive break point clusters) comprising of 665,520 break points/crests and measured instantaneous peel angle (Figure 2; Figure 3; an example of multi-wave tracking is available at: https://www.ecoast.co.nz/surf-break-management-1).

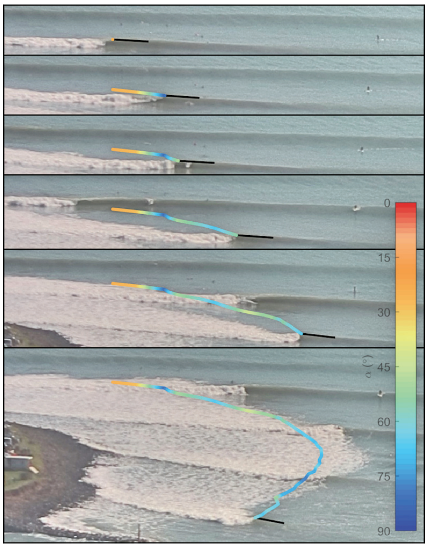


Figure 2: An example breakpoint and crest tracking with instantaneous peel angle (α). From Atkin (2021).

A standout feature of the data set is a lack of breakpoints at the eastern end of the point; a hydrographic survey undertaken at the start of the data collection period indicates an elongated depression in this area that is likely to be a persistent seabed feature (Figure 3). Previous work studying Waikeri measured peel angles between 30-75° (Hutt et al., 2001; Scarfe 2008), with a mean value of 65°, which is comparable to the mean value of 60° in this dataset. The western end of the point break at Waikeri is known as 'The Ledge' and is associated with waves that break in a fast and hollow manner (Figure 4). This is consistent with this dataset where peel angles are lower in the vicinity of The Ledge where faster breaking occurs.

While the average rideable length of ~27 m is not consistent with the previously recorded 71.6 m based on surfer GPS location (Borrero et al., 2019), the camera system is collecting all surfable conditions and not just those favourable conditions that surfers tend to target. The maximum length of surfable wave recorded by the system is 275 m (Figure 2), ~125 m longer than that recorded by GPS. Neither approach provides information about wave shape, which is integral to how a wave is utilised by a participant. Further work has considered correlations between environmental variables (Atkin, 2021), although more detailed analysis will include qualities such as section length, wave breaking speed, and the implications for surfability.

This type of applied technology will likely play a big role in the establishment of natural baselines required for sustainable

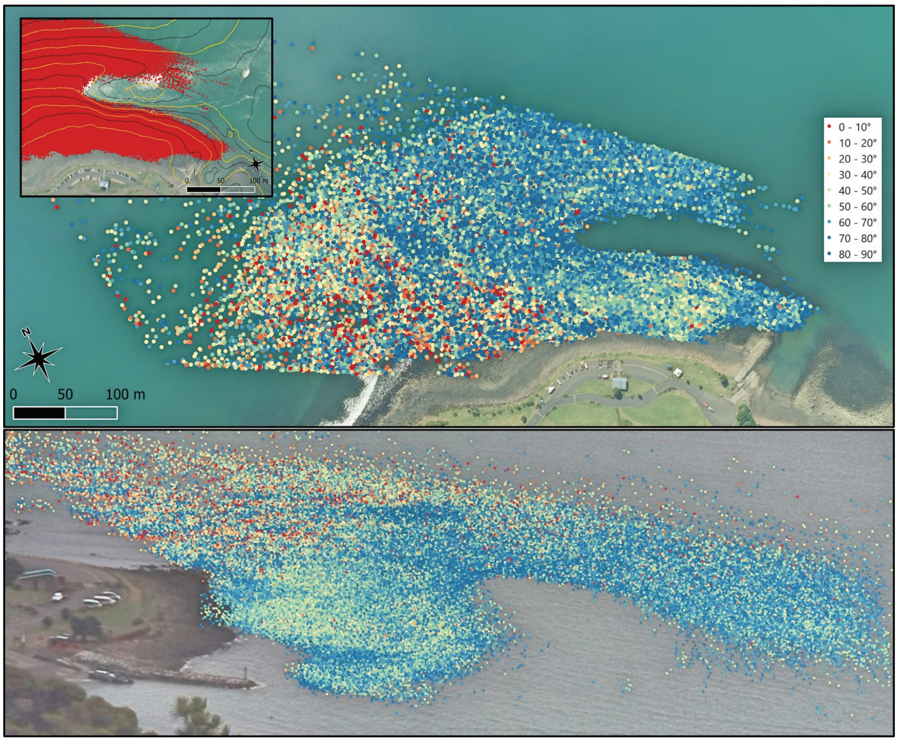


Figure 3: Top (from Atkin, 2021): break points with peel angle value detected between May 2017 and June 2020. The insert shows the same breakpoint locations with a depth isobath overlay. The nearest contour to land is -0.5 m (MSL), contours are in 1 m increments. Bottom: break points coloured with peel angle value overlain on a cropped image from the camera system.

Figure 4: Waikeri resident expert Chris Malone riding in the vortex of the wave, or barrel, at The Ledge (Image courtesy of Cory Scott, nzsurfmag.co.nz).

management. This approach can and will be readily replicated at other sites; but the application of machine learning for coastal monitoring of coastal hazards could very readily be incorporated into the same system, especially given the speed of detection, which lends itself to real-time monitoring. As for the ANZASR, the trust has sponsored the Surf Science, Engineering and Management special topic at the next Australasian Coast and Ports conference, with a plan to hold a hui regarding how our management strategies can be improved.

References

Atkin, EA (2010). *The impact of an ASR on breaking wave conditions at Boscombe, UK*. Thesis: University of Southampton, UK.

Atkin, EA (2021). Machine-learned peel angles for surfing wave quality monitoring. *Australasian Coasts & Ports 2021 Conference Proceedings*, Christchurch, New Zealand.

Atkin, EA, et al. (2019). *Management guidelines for surfing resources*. Raglan, Aotearoa New Zealand: Aotearoa New Zealand Association for Surfing Research.

Atkin, EA, et al. (2021). Deep learning object detection application to surfing wave quality. *Manuscript in preparation*.

Borrero, JC, et al. (2019). Application of Rip Curl SearchGPS watch data for analyzing surf breaks. In: Bryan, KR & Atkin, E (eds.), Surf break management in Aotearoa New Zealand. *Journal of Coastal Research*, Special Issue No. 87, p. 55-69.

Bryan, KR and Atkin, E (eds.) (2019). Surf break management in Aotearoa New Zealand. *Journal of Coastal Research*, Special Issue No. 87.

Hutt, JA, et al. (2001). Classification of surf breaks in relation to surfing skill. In: Black, KP (ed.) Natural and artificial reefs for surfing and coastal protection, *Journal of Coastal Research*, Special Issue No. 29, p. 66-81.

Jocher, et al. (2020). Ultralytics/yolov5 Version v3.0. DOI: 10.5281/zenodo.3983579

McIntosh, R, et al. (2018). Development of an automated peel angle detection system for the Manu Bay surf break. New Zealand Coastal Society, *New Zealand Coastal Society Conference*, Gisborne, New Zealand.

Mead, ST and Atkin, EA (2019). Managing issues at Aotearoa New Zealand's surf breaks. In: Bryan, KR & Atkin, E (eds.), Surf break management in Aotearoa New Zealand. *Journal of Coastal Research*, Special Issue No. 87, p. 13-22.

Scarfe, B (2008). *Oceanographic considerations for the management and protection of surfing breaks*. PhD thesis, University of Waikato, New Zealand.

Thompson, M, et al. (2021). Wave peel tracking: A new approach for assessing surf amenity and analysis of breaking waves. *Remote Sensing*, 13, 3372.

Walker, JR, et al. (1972). Recreational surfing on Hawaiian reefs. *Proceedings of the 13th Coastal Engineering Conference*, Vancouver, Canada.

Weppe, S, and Shand, T (2019). Modelling surf break wave mechanics with SWASH – an application to Mangamaunu Point Break (Kaikōura, New Zealand). *Australasian Coasts & Ports 2019 Conference*, Hobart.

Appendix F. Co-authorship Form

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Co-Authorship Form

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work**. Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 3: Atkin, E., Hume, T., Mead, S., Bryan, K and Waiti, J., 2017. Remote Sensing, Classification and Management Guidelines for Surf Breaks of National and Regional Significance. Coasts and Ports 2017 Conference – Cairns, 21-23 June 2017.

Nature of contribution by PhD candidate	Lead author of paper, lead author of techncial report on which paper is based, Key researcher of overarching project.
Extent of contribution by PhD candidate (%)	90 %

CO-AUTHORS

Name	Nature of Contribution
Dr Terry Hume	Review of draft paper. Key researcher in overarching project.
Professor Karin Bryan	Lead researcher in overarching project.
Dr Shaw Mead	Key researcher and science leader in overarching project.
Dr Jordan Waiti	Key researcher in overarching project.

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Dr Terry Hume	[signature]	11/10/2022
Professor Karin Bryan	[signature]	11/10/2022
Dr Shaw Mead	[signature]	11/10/2022
Dr Jordan Waiti	[signature]	11/10/2022

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Co-Authorship Form

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work**. Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 4: Atkin, E., Hume, T., Mead, S., Bryan, K and Waiti, J., 2019. Management Guidelines for Surfing Resources. Australasian Coasts and Ports 2019 Conference – Hobart, 10-13 September 2019.

Nature of contribution by PhD candidate	Lead author of paper, lead author of techncial report on which paper is based, Key researcher of overarching project.
Extent of contribution by PhD candidate (%)	90 %

CO-AUTHORS

Name	Nature of Contribution
Dr Terry Hume	Key researcher in overarching project.
Professor Karin Bryan	Review of draft paper. Lead researcher in overarching project.
Dr Shaw Mead	Key researcher and science leader in overarching project.
Dr Jordan Waiti	Key researcher in overarching project.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Dr Terry Hume	[signature]	11/10/2022
Professor Karin Bryan	[signature]	11/10/2022
Dr Shaw Mead	[signature]	11/10/2022
Dr Jordan Waiti	[signature]	11/10/2022

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

Co-Authorship Form

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work**. Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 5: Atkin, E.A, Reineman, D.R., Reiblich, J, and Revell, D.L., 2020. Applicability of Management Guidelines for Surfing Resources in California. Shore and Beach, 88 (3).

Nature of contribution by PhD candidate	Lead author of paper, lead author of techncial report on which paper is based, developed paper structure and lead the research aims. Led Introduciton, Guideines, Linkages, Discussion and Conclusion sections.
Extent of contribution by PhD candidate (%)	85 %

CO-AUTHORS

Name	Nature of Contribution
Dr Dan Reineman	Second author, lead on state setting section. QC on discussion
Dr Jesse Reiblich	Third author, lead on federal setting section.
Dr Dave Revell	Fourth author, lead on local setting section.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Dr Dan Reineman	[signature]	10 Oct 2022
Dr Jesse Reiblich	[signature]	10 Oct. 2022
Dr Dave Revell	[signature]	10 Oct 2022

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Co-Authorship Form

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. Please include one copy of this form for each co-authored work. Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 6: Atkin, E.A and Greer D., 2019. A Comparison of Methods for Defining a Surf Break's Swell Corridor.
In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 70–77. Coconut Creek (Florida), ISSN 0749-0208.

Nature of contribution by PhD candidate	Lead author, developed research structure, undertook all analysis and the bulk of numerical modelling, and discussion.
Extent of contribution by PhD candidate (%)	90 %

CO-AUTHORS

Name	Nature of Contribution
Dougal Greer	Additional numerical modellign work load, assisted with RPA concept development. Review.10%

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Dougal Greer	Dougal	10/10/2022

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Co-Authorship Form

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work**. Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 7: Atkin, E.A., Mead, S.T. and Phillips, 2019. Preliminary Investigations of offshore Wave Preconditioning. In: Bryan, K.R. and Atkin, E.A. (eds.), Surf Break Management in Aotearoa New Zealand. Journal of Coastal Research, Special Issue No. 87, pp. 78–90. Coconut Creek (Florida), ISSN 0749-0208.

Nature of contribution by PhD candidate	Lead author of paper, developed research structure and undertook all analysis, numerical modelling and discussion.
Extent of contribution by PhD candidate (%)	90 %

CO-AUTHORS

Name	Nature of Contribution
Dr Shaw Mead	Techncial critique, discussion and review. 5%
Assoc. Prof. Dave Phillips	Techncial critique, discussion and review. 5%

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Dr Shaw Mead	Shaw Mead	11/10/22
Assoc. Prof. Dave Phillips	David Phillips	11/10/22

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website: http://www.waikato.ac.nz/sasd/postgraduate/

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Co-Authorship Form

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work.** Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 8: Atkin, E.A., Davies-Campbell, J. and McIntosh, R., 2022. Deep Learning Object Detection Application to Surfing Wave Quality. Coastal Engineering, 37.

Nature of contribution by PhD candidate	Lead author, developed research structure, tools and models, all analysis and discussion.
Extent of contribution by PhD candidate (%)	90 %

CO-AUTHORS

Name	Nature of Contribution
Jai Davies-Campbell	Preprocessing - annotation of images. Review.
Rhys McIntosh	Coding of annotation interface. Review.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Jai Davies-Campbell	[signature]	11/10/2022
Rhys McIntosh	[signature]	11/10/2022