Quantitative Methodology for Measuring Natural Character in New Zealand's Coastal Environments

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Abstract

Anecdotal evidence points to an overall loss of coastal natural character in New Zealand since preserving the natural character of the coastal environment first became a statutory policy-goal in 1973. Today the preservation of the natural character of the coastal environment is one of the matters of national importance in the Resource Management Act 1991 (development control legislation) and one of the purposes of the Reserves Act 1977 (protected area legislation). There has, however, been no quantitative measurement or systematic monitoring of changes in overall natural character.

The purpose of this thesis has been to develop a robust quantitative methodology for measuring natural character and its change using a consistent framework across terrestrial, freshwater and marine coastal environments. While methodology development took place in Northland, New Zealand, the methodology has been designed to be applied throughout New Zealand. With modification it would also have applicability in other countries.

A comprehensive definition of natural character was developed for the New Zealand environmental, legal and policy contexts that also addressed the role of perception. Court decisions on appeals lodged under the Resource Management Act were found to be generally consistent with this definition.

The Quantitative Index for measuring the Natural Character of the Coastal Environment (QINCCE) methodology was developed using indicators (and environment-specific parameters) derived from the comprehensive definition of natural character. A consistent framework is used for measuring natural character across terrestrial, freshwater and marine coastal environments. The methodology can be applied at a range of scales and for a range of purposes. For each broad class of coastal environment there is a core set of parameters that are used to calculate three sub-indices for each plan-view unit:

- An ecological naturalness index (ENI)
- A hydrological and geomorphological naturalness index (HGNI)
- A freedom from buildings and structures index (FBSI)

These three sub-indices are combined to give an overall natural character index (NCI) for each unit, which can be multiplied by 100 to give a natural character score between 0 and 100. Second tier parameters and alternative measurement perspectives have been developed for those situations where additional detail is required.

Several key parameters are measured relative to the reference condition *present-potential natural state*. One is *Score representing progress towards present-potential cover* where *present-potential cover* is the terrestrial and aquatic land cover that would be present today had natural processes proceeded without the arrival of humans, the species they introduced and the consequential changes to the environment. Scoring tables for measuring progress towards *present-potential cover* have been developed for eastern Northland. Hydrological and geomorphological naturalness is assessed relative to the equivalent *present-potential natural state.* Protocols for addressing interactions between the hydrological and geomorphological, and cover parameters have been developed. This includes distinguishing between natural versus human-induced, and on-site versus off-site sources of disturbance.

As part of the methodology refinement process, 113 “informed” participants scored their perceptions of natural character for 40 coastal environment photographs. These perceived scores were compared with scores calculated for the same photographs using the QINCCE methodology applied using an oblique *Viewpoint* perspective. The results assisted with the subsequent refinement of the scoring protocols for some parameters, and the construction and combination of the QINCCE indices.

Keywords
Aquatic, baselines, , case law, ecology, ,disturbance, geomorphology, hydrology, indicators, indices of natural character, invasive species, marine, naturalness, Northland, policy, public perception, reference conditions, terrestrial, vegetation succession

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Table of contents

List of tables

List of figures

Abbreviations used

BSIS	Buildings and Structures Impact Score
CNCS	Calculated Natural Character Score
ENI	Ecological Naturalness Index
FBSI	Freedom from Buildings and Structures Index
HGNI	Hydrological and Geomorphological Naturalness Index
LDA	Linear discriminant analysis
NCI	Natural Character Index
NCS	Natural Character Score (NCI×100)
NZCPS	New Zealand Coastal Policy Statement
QINCCE	Quantitative Index for measuring Natural Character of the Coastal Environment
PNCS	Perceived Natural Character Score

1 Introduction

1.1 The policy context

New Zealand has a statutory policy goal of preserving the natural character of the coastal environment and various freshwater environments and their margins. This was developed in response to widespread public concern in the late 1960s and early 1970s about the rapid rate of coastal and lake margin development (Minister of Works and Development 1974). An early 1973 statement of intent to use the "full powers" of the planning legislation to protect coastal and lakeshore areas was followed by the introduction of a national policy on land (Maplesden & Boffa Miskell 2000). This principle-based policy:

- recognised the national importance of coastal land;
- sought provision for a wide range of recreational opportunities on the coast; sought retention of sufficient native coastal flora and fauna in its natural state, as well as unique and typical coastal scenery;
- required the definition of land needed for urban uses and land to be excluded from these;
- sought that development of coastal land for urban and holiday purposes be in sympathy with the landscape; and
- sought the protection of dune areas to maintain stability of coastal lands. (Maplesden & Boffa Miskell 2000)

Seven months later the Town and Country Planning Act 1953 was amended by the addition of a new section 2B which stated

"*The following matters are declared to be of national importance and shall be recognised and provided for in the preparation, implementation and administration of regional and district schemes*:

(a) "The *preservation of the natural character of the coastal environment and the margins of lakes and rivers and the protection of them from unnecessary subdivision, use and development*…"

When this Act was replaced by the Town and Country Planning Act 1977 this provision was included as section 3(1)(c). In spite of the intentions of the Government in power in the early 1970's, the absence of specific government policy led to this provision being misinterpreted and undermined by the Planning Tribunal. As a result, the purpose of the Town and Country Planning Act 1977 with respect to the coastal environment was never widely achieved (Hilton 1992). It was not until a landmark 1989 Court of Appeal decision *Environmental Defence Society vs Mangonui County Council* that Justice Somers held that "*...the interests of the district are subordinate to the declared matters of national importance"* It was really from this time that planning legislation could begin to have an effective role in preserving the natural character of the coastal environment.

While drafted in 1974, the equivalent natural character statutory policy goal was incorporated into the Reserves Act 1977. One of the three purposes (section 3(1)(c))of this Act includes "…*fostering and promoting the preservation of the natural character of the coastal environment and of margins of lakes and rivers and the protection of them from unnecessary subdivision and development*." To assist with the implementation, section 4(2) of the Act requires that the "…*survey of the sea coast, its bays and islets and offshore islands [and] of lakeshores and riverbanks* " be completed and from time to time kept under review.

In the 1970's there was an active programme to preserve coastal, and lake and river margin natural character by the identification of areas of value (through systematic survey) and the protection of these areas (by way of acquisition). These survey and purchase actions were linked to the local authority planning processes. The annual reports to Parliament prepared by the then Ministry of Works and Development (central government planning agency) and the Department of Lands and Survey (national parks and reserves management agency) described the progress of the multi-agency committee and working group which guided reserve surveys and recommended coastal and lake and river margin reserve acquisitions.

The then Department of Lands and Survey surveyed coastal land county by county identifying priorities for protection. Each completed county report was presented to the local council for them to incorporate the findings into their district schemes (prepared under the Town and Country Planning Act 1977), primarily by designations of proposed reserves (Department of Lands and Survey 1974, 1977). Designated coastal areas were progressively acquired although the available funding was never enough.

In the 1980's the focus of environmental survey on unprotected lands changed. The Protected Natural Areas Programme (PNA Programme) was established to assist the Crown meet its requirements under another purpose of the Reserves Act- section 3(1)(b). This purpose is to ensure as far as possible, "*the survival of all indigenous species of flora and fauna…in their natural communities and habitats, and the preservation of representative samples of all classes of natural ecosystems and landscapes which in aggregate originally gave New Zealand its own recognisable character*" For the PNA survey programme New Zealand was divided into 85 ecological regions and 268 ecological districts (Biological Resources Centre 1983). Surveys proceeded gradually and over time a variety of mechanisms have been used to secure protection for some of the identified important areas and features. This included legal protection (often without ownership change) under the Reserves Act and other statutes.

In 1987 the then new Department of Conservation took over the functions and administration of the Reserves Act 1977 as well as a variety of other conservation related legislation. As the focus of unprotected land survey changed so did reserve acquisition priorities. The price of coastal and lake-margin land also began to increase substantially. By the early 1990's the use of designations in planning documents to identify future reserves for conservation purposes was no longer a preferred tool of government agencies.

A late 1980's review of a large number of statutes affecting land, air and water (including the Town and Country Planning Act 1977) culminated in the Resource Management Act 1991. The purpose of this Act is to promote the sustainable management of natural and physical resources. As part of achieving this purpose there are five matters of national importance with the first being: "*The preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development"* (section 6(a)).

The Act defines the coastal marine area (section 2) to extend from the outer limits of the territorial sea to mean high water springs and includes a specific mechanism for defining the coastal marine area inner boundary at river mouths. The inland boundary of the coastal environment is not defined in the Act.

The Act provides for a hierarchy of planning instruments. In the coastal environment this begins with the mandatory New Zealand Coastal Policy Statement (NZCPS). The first NZCPS (Minister of Conservation 1994) was replaced by the second NZCPS (Minister of Conservation 2010) on 3 December 2010. Both included a number of policies related to the preservation of the natural character of the coastal environment, with the most recent (Minister of Conservation 2010) containing additional provisions including a requirement to assess coastal natural character by mapping or otherwise identifying areas of at least high natural character.

Regional policy statements (mandatory) form the next tier. Below this are plans. Mandatory regional coastal plans contain policies, rules, standards and other methods for the coastal marine area and are approved by the Minister of Conservation. Some regional coastal plans include policies for the coastal environment above mean high water springs. Other, non-mandatory, regional plans may contain rules (e.g. regulating discharges and earthworks) that apply to the coastal environment and/or to the wider catchment. Mandatory district plans contain the rules and standards for the coastal environment above mean high water springs. These plans provide the primary framework for managing the extent and type of terrestrial coastal development.

If this planning regime is to be effective in “protecting” the natural character of the coastal environment there should be sufficient appropriate policies, rules, standards and other methods in the relevant Resource Management Act policy statements and plans. Such provisions should be properly implemented by councils, and the environmental outcomes monitored. Depending on the outcomes of monitoring, policy statements and plans should be revised as necessary to improve environmental outcomes relating to coastal natural character. This policy effectiveness loop should operate at all relevant levels of governance, although it would be sensible to allocate specific monitoring responsibilities to improve accountability.

Even though the policy to preserve the natural character of the coastal environment has been part of both planning/development control and protected area legislation since 1977, publications over the last 15 years have identified serious ongoing losses of coastal natural character (Peart 2009) and inadequate responses by local government (Office of the Parliamentary Commissioner for the Environment 1996; Rosier 2004, 2005; Peart 2009). In a 1996 investigation into how three territorial local authorities were addressing their coastal environment responsibilities, the Office of the Parliamentary Commissioner for the Environment (1996) concluded that "*despite a longstanding obligation to preserve the natural character of the coastal environment, councils have not made this a high priority*"

Eight years later, the ten year review (Rosier 2004) of the first NZCPS found that while the Statement's policies had been addressed in regional policy statements and regional coastal plans, this was not the case for district plans and decisions on subsequent land and subdivision consent applications. The district plans had made little detailed provision for protecting the natural character of the coastal environment in the rules and standards affecting coastal subdivision, land use and development (Rosier 2005). The overall area of poorest implementation was the monitoring of environmental outcomes and assessing the degree to which plans and policies had influenced environmental results (Rosier 2004, 2005). Although the second New Zealand Coastal Policy Statement (Minister of Conservation 2010) became operative just as this thesis was being submitted for examination, the final version of the thesis has been updated to address the second NZCPS.

1.2 The environmental context

The continent fragment Zealandia is thought to have separated from remnants of the ancient supercontinent Gondwana about 85-80 million years ago (Gibbs 2006). Although some have considered that the entire Zealandia was flooded during a major marine transgression during the Oligocene (about 22 million years ago) research on the early Miocene fauna and other data suggests this is unlikely (Tennyson 2010). The resulting unique and vulnerable biota is derived from the original Gondwana biota with other organisms arriving from time to time. There was a very high level of endemism in both plant and animal species with 70% of land and freshwater birds and 85% of flowering plant species being endemic (Taylor & Smith 1997). Many bird species evolved unique life forms often losing the power of flight and feeding on the ground in the absence of terrestrial predators. The only terrestrial mammals at the time of human settlement were three species of bat, two of which unusually had evolved to feed extensively on the ground (Wilson 2003). The ground-based habits of many indigenous bird species made them highly vulnerable to human hunting, and subsequently to introduced mammalian predators.

Humans settled in New Zealand only 730 years ago (Wilmshurst et al. 2008). They hunted many bird species, cleared and otherwise destroyed many indigenous ecosystems and introduced many alien plant and animal species. This led to the extinction of many unique New Zealand species and today New Zealand's level of threatened species is rated amongst the highest in the world (Hitchmough et al. 2007; Ministry for the Environment 2007).

Seabirds once played a widespread role in New Zealand ecosystems (e.g. increasing soil fertility, changing pH) with early declines due to hunting (Hamel et al. 2003) and more recent declines resulting from predation by introduced mammals (Bellingham et al. 2010). Even today New Zealand is the world's "seabird capital" with 23% of the world's seabird fauna breeding here and 10% only breeding here (Taylor 2000).

Prior to human arrival, about 78% of New Zealand was forested. Today, indigenous forest cover is 23%, with much of that remaining being in steep mountainous country. Farmland now makes up 52% of the country which is much higher than the world average of 37% (Tong & Cox 2000). Nationally, 10% of wetlands present before the arrival of humans remain. In the North Island this is reduced to 4.9% (Ministry for the Environment 2007a).

Introduced species have had a major impact on the remaining indigenous terrestrial and freshwater biota and ecosystems. Browsing by introduced mammalian herbivores induces population declines of select plant species, changes regeneration patterns and favours the spread and consolidation of introduced plant species (Lee et al. 2010). Predation by introduced mammals is primarily responsible for current declines and limitations of forest birds at the national level, although locally forest loss can be the major reason (Innes et al. 2010). Freshwater ecosystems have also been adversely affected by introduced species. For example introduced trout have caused widespread reductions in the distribution and abundance of native galaxiid fishes (a family dominated by threatened species) (McIntosh et al. 2010).

The natural character of many fresh and estuarine waters has been lost or degraded by drainage, construction of flood control channels and stopbanks, removal of riparian vegetation, point and non-point discharges. Approximately one third of New Zealand lakes have poor water quality with 13% of monitored lakes being extremely degraded and commonly subject to algal blooms (Ministry for the Environment 2007a, b). Nitrogen and phosphorus levels are 2-6 times higher in lakes with pastoral catchments compared to levels in lakes with naturally vegetated catchments. Water clarity in lakes of pastoral catchments is one fifth of that found in lakes in natural catchments (Ministry for the Environment 2007b).

While New Zealand marine environments are relatively healthy by international standards, approximately 30% are disturbed by human activities (Ministry for the Environment 2007a). Large-scale commercial fishing removes large numbers of organisms, destroys marine habitats and disrupts marine food chains (Ministry for the Environment 2007a). While industrial scale fishing largely began in the 1950s there had been considerable harvest of some species before then (e.g. (Parsons et al. 2009). Overfishing using destructive techniques led to the commercial extinction of the once extensive mussel reefs in the Firth of Thames (McLeod 2009). Ships have introduced new species that have had, or are likely to have, an adverse impact on marine ecosystems.

Considerable areas of sheltered coastal margins have been modified by human activities such as land drainage, causeway construction, seawalls, reclamation and other development. Many near-shore marine environments have been affected by excessive nutrients and increased levels of sediment derived from human land use activities (Morrison et al. 2009).

Many of the most dramatic changes to terrestrial and freshwater coastal environments happened in the early years of Polynesian and especially European settlement of New Zealand. The Northland coastal environment is, however, under continuing pressure from increasing human populations and development pressures as well as the threats posed by alien plant and animal species. From the mid 1990s until 2006 there were dramatic increases in often large coastal holiday homes and in 'lifestyle' blocks (Peart 2009). Speculative coastal subdivision, especially in the Far North, has led to the template of development being established in many areas well ahead of actual demand (Peart 2009). More and larger settlements are likely to lead to increased invasion of alien plant species into native ecosystem remnants (Sullivan et al. 2005). Cats and dogs, as well as introduced mammalian predators, threaten native coastal wildlife.

Not all recent trends have been negative for natural character in the Northland terrestrial coastal environments. Some areas of previously marginal farmland have been retired from farming (e.g. parts of Bay of Islands) and left to revert to native or a mixture of native and introduced species following the economic restructuring of the 1980s that removed various farming and land development incentives (Froude et al. 1985). In Northland there are a number of projects that have eradicated alien mammal species (e.g. eastern islands in the Bay of Islands) or more typically undertake intensive pest control (e.g. Russell, Cape Brett and Purerua Peninsulas in the Bay of Islands). Several recent exclusive coastal subdivision developments have planted large numbers of native plants in former farmland. There are community groups and others planting native dune-binders and managing access routes in some vulnerable dunelands.

Many of the dramatic changes to the marine environment of Northland harbours and estuaries happened between 1840 and 1970 (e.g. reclamations, causeways, and large scale dredging). More recent marine environment changes have included new port development (e.g. Marsden Point), marinas and associated facilities, road infrastructure and aquaculture (especially of the introduced Pacific oyster). Accelerated marine sedimentation resulting from past and present catchment land uses continues. Modern equipment and technology has allowed commercial and recreational fishers to expand their range and effectiveness. Introduced species have continued to arrive and spread in Northland ports and harbours. On the positive side, initial local seagrass restoration trials are taking place in Whangarei Harbour. While the number of no-take marine reserves has gradually expanded nationally, only a very small proportion of the 3200km Northland coastline is protected in this way.

1.3 Natural character and related concepts

Natural character has not been defined in New Zealand legislation or in either of the New Zealand Coastal Policy Statements (Minister of Conservation 1994, 2010). Considerable case law has been developed around the concept of natural character and the implementation of the relevant legislation. In chapter 3 I describe the process used to develop the following comprehensive published definition of natural character:

Natural character occurs along a continuum. The natural character of a 'site' at any scale is the degree to which it:

- *is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous 'biological artefacts'*
- *exhibits fidelity to the geomorphology, hydrology, and biological structure, composition, and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable with reference conditions*

Human perceptions and experiences of a 'site's' natural character are a product of the 'site's' biophysical attributes, each individual's sensory acuity, and a wide variety of personal and cultural filters.

The 2010 New Zealand Coastal Policy Statement (Minister of Conservation 2010) was gazetted after this definition was published. While it does not include a definition, it does list different types of matters that may be part of natural character (policy 13(2)). While policy 13 does not change the core definition of natural character developed in chapter 3, for the avoidance of doubt, several additional context statements are proposed in the postscript to Chapter 3.

Terms of relevance to the concept of natural character can be interpreted differently by different people. Box 1.1 defines some of terms of relevance to the concept of natural character in New Zealand.

Box 1.1; Terms that are relevant to the concept of natural character

Biological artefact areas: human management of the biota prevails and is evident in the biological patterns and processes. Examples include agricultural and horticultural areas, production forestry, gardens and lawns.

Indigenous species: species naturally found in New Zealand. This includes species that are self-introduced. It does not include species that have been introduced in any way by humans. Species that are indigenous to New Zealand may also be indigenous in some other countries

Endemic species: indigenous species that are only found in New Zealand. New Zealand has a very high rate of endemic species, exceeded only by a few isolated island groups such as Hawaii

Introduced species: non-indigenous species, introduced by humans

Naturalised species: introduced species that have established breeding populations in the wild and are able to survive and expand in the wild without human input.

Invasive species: introduced species that invade and damage natural ecosystems. Some also damage human production systems (biological artefact areas)

1.4 Ecological natural character

Ecological naturalness is a core component of natural character. This is reflected in New Zealand case law (Chapter 4) and the New Zealand Coastal Policy Statement (Minister of Conservation 2010). The methodology developed for measuring natural character uses specified reference conditions (or the equivalent baselines) for determining the level of ecological naturalness (as well as hydrological and geomorphological naturalness and the impacts of human structures and other activities).

The reference conditions used for assessing ecological naturalness are *present-potential cover* or state. *Present-potential cover* or state (Chapters 6 and 7) is that which would be expected if humans, and the species they introduced, had not arrived in New Zealand but natural physical processes had still occurred. This is modified slightly to recognise the irreversibility of species extinctions. Where a "site" or "area" exhibits 100% fidelity to the ecological structures, composition, patterns and processes of the *present-potential state*, ecological naturalness is 100%.

At a particular site natural disturbance processes may mean that the *present-potential cover* is not necessarily the "climax" (in the context of classical ecological succession theory) cover for that site. There is a substantial body of literature around the concept of ecological succession (chapter 7). Excluding large-scale catastrophic disturbances (such as major volcanic eruptions or strong tsunami generated by a large local earthquake) disturbance effects are typically expressed at the scale of a patch or a collection of patches. The paradigm of patch dynamics proposes that ecosystem patterns and processes take place within different sized patches that are defined by abiotic and biotic attributes that change over time and space (Wu & Loucke 1995, Zimmerman et al. 2010). The spatial boundaries of patches may change regularly in highly dynamic coastal environments (e.g. estuaries, dunelands, headlands and near-shore open coast marine environments). Coastal environments subject to ongoing very regular natural disturbance (e.g. river mouths, barrier spits) may remain in an early successional stage. The challenges of determining *present-potential cover* at the patch scale and in the context of different types, magnitudes and frequencies of natural disturbance are discussed further in Chapter 7.

In the New Zealand forest context, there can be dense regeneration of some tree species (e.g. kauri (*Agathis australis*) (Ogden et al. 1987); kanuka (*Kunzea ericoides*) and pohutukawa (*Meterosideros excelsa*) (Atkinson 2004) following a moderate-large disturbance. This can lead to a self-thining stand with a canopy species regeneration gap. Once the canopy is mature wind-throw disturbance can create gaps for recruitment by canopy tree or other species. This process can be easily deflected by invasive species. Other indigenous canopy species can resprout after disturbance (e.g. tairaire (*Beilschmedia tairaire*) and mahoe (*Melicytus ramniflorus*), as can a number of invasive tree species (e.g. tree privet (*Ligustrum lucidum*), monkey apple (*Acmena smithii*) . Such resprouting can bend successional directionality (Caplat & Anand 2009). Appendix 5 describes the successional trends found in a variety of Northland aquatic and terrestrial aquatic environments.

1.5 Lack of monitoring of natural character outcomes and plan effectiveness

Anecdotal evidence points to an overall loss of coastal natural character in Northland since the preservation of natural character of the coastal environment became a statutory policy-goal in 1973. The actual change does of course vary from place to place. There has, however, been no systematic monitoring of the changes in overall natural character for different parts of Northland or elsewhere in New Zealand. Without this monitoring the policy effectiveness loop, as described in section 1.1, does not operate properly for the natural character policy goal. While some (primarily regional) councils monitor changes in selected components of natural character, there is no comprehensive monitoring of the different dimensions of natural character as an integrated whole across terrestrial, freshwater and marine coastal environments.

Rosier (2005) identified the poorest aspects of implementation for the 1994 New Zealand Coastal Policy Statement as being: a lack of monitoring of the environmental outcomes; and inadequate assessment of the degree to which plans and policies had influenced the environmental outcomes. Without this information government agencies and councils can not accurately measure the effectiveness of their policies, rules, incentives and actions. A common dictum states "what is measured, is what is managed". A corollary could be "what is not measured, is not managed effectively".

1.6 Research questions and objectives

The overall question that this research addresses is:

How can the environmental outcomes of New Zealand's coastal natural character policy-goals be measured and evaluated?

The overall objective of this research has been:

To develop a robust quantitative methodology to measure natural character and its change, and thereby measure performance in implementing the New Zealand natural character statutory policy-goals.

The overall research question and objective are underpinned by a set of more detailed questions and objectives (Table 1.1).

Table 1.1: Secondary research questions and matching objectives

Research questions	Research objectives
1. What is the 'first-principles' definition of natural character, especially in the New Zealand environmental, legal and policy context?	1. To develop a comprehensive definition of natural character that addresses the New Zealand context.
2. What is the role of human perception in the understanding of natural character?	2. To clarify the role of perception with respect to a definition of natural character.
3. How does this definition match with interpretations of natural character that can be derived from New Zealand court decisions?	3. To confirm that the developed definition is consistent with New Zealand court decisions.
4. What type of quantitative or semi-quantitative methodology could be applied across terrestrial, freshwater and marine environments to measure natural character at different scales?	4. To develop and refine a quantitative methodology for measuring natural character and its change; using a consistent framework across terrestrial, freshwater and marine coastal environments; applicable at a range of scales; and fit for a range of purposes.

Research questions	Research objectives
5. What type of practical approach can be used to measure key components of environmental naturalness at different scales in terrestrial, freshwater and marine coastal environments?	5. To develop a set of parameters that addresses key components of environmental naturalness, where parameter details vary as required in order to address different types of coastal environment and additional parameters that can be used for more detailed assessments.
6. How can the measurements of different types of parameters be combined so that overall levels of natural character can be reported and natural character levels for different types of coastal environment be compared?	6. To develop an analysis framework that combines parameter data into appropriate sub-indices that can be combined to give an overall index of natural character thereby allowing levels of natural character in different types of coastal environment to be compared.
7. What reference conditions or baselines should be used for assessing natural character to facilitate the aggregation and comparison of results from different types of coastal environments?	7. To determine natural character reference conditions for those parameters that measure components of environmental naturalness and develop scoring protocols for assessing the progress towards those reference conditions, thereby allowing naturalness levels in different types of coastal environment to be compared.
8. Could the perception of natural character by informed participants guide the relative weighting of different components in an overall natural character assessment, and do perceptions change in different coastal environments?	8. To undertake and utilise a study of natural character perception by “informed” persons to assist with methodology refinement. This may include using different weightings within an overall natural character index for different types of coastal environment. *
9. What participant attributes may affect their scoring of natural character?	9. To evaluate whether particular attributes of the “informed” participants may affect their assessments of natural character levels in different contexts.

* This question was broadened during the research as described in Chapter 8

1.7 Thesis structure

This thesis combines a published paper (Chapter 3), several papers that will be submitted for publication after amendment to address journal requirements

(Chapters 4, 5, 7 and possibly 8) and thesis chapters (remainder). Table 1.2 lists the chapters with the relevant research questions and objectives.

Table 1.2: Thesis chapters and their relationship to the research questions and objectives

Chapter number	Chapter title	Research questions	Research objectives
1	Introduction	n/a	n/a
2	Methods used to develop natural character measurement methodology	n/a	n/a
3	The nature of natural: defining natural character for the New Zealand context	1, 2	1,2
4	Comparison between New Zealand Resource Management Act case law and “first-principles” definition of natural character	3	3
5	QINCCE: a quantitative methodology for measuring the natural character of the coastal environment	4, 6, 7	4, 6, 7
6	QINCCE methodology parameter derivation and measurement	4	4
7	QINCCE methodology: comparing current state with present-potential natural state for cover, geomorphology and hydrology	5, 7	5, 7
8	Using comparison between “informed” perception and objective measures of natural character to refine methodology for measuring natural character	8, 9	8, 9
9	Case studies	6,8	6,8
10	Conclusion	all	all

Chapter 2 provides a summary of the strategy used to develop the QINCCE methodology for measuring coastal natural character. Chapter-specific methodology (e.g. for Chapter 8) is addressed in the relevant chapter.

Chapter 3 develops a comprehensive definition of natural character. This is a paper that has been published in the *New Zealand Journal of Ecology*. Chapter 4 compares the definition developed in chapter 3 with an evaluation of the extensive body of case law on natural character developed under the Resource Management Act.

Chapter 5 sets out the framework for the quantitative methodology developed in this thesis for measuring the natural character of the coastal environment (QINCCE). The QINCCE methodology uses primarily state indicators that address key components of the natural character definition. A standard framework is used across terrestrial, freshwater and marine coastal environments with specific parameters tailored to the particular environment. The core parameters contribute to three sub-indices that are combined into an overall natural character index. Chapter 6 provides additional information about both the core and *Tier-Two* parameters used in the QINCCE methodology.

Chapter 7 develops the concept of *present-potential cover* and *present-potential natural state* as generic reference conditions used by several of the core parameters. It constructs a framework for measuring the core parameter- *Score for progress towards present-potential cover*. *Present-potential-cover* is described for various Northland coastal environments and scoring tables for measuring *progress towards present-potential –cover* are compiled for a subset of environments.

Chapter 8 compares natural character scores from 113 "informed" participants with equivalent scores calculated using the QINCCE methodology. This process assisted with refining: the scoring protocols used for several core parameters, the final combination of parameters used in the Ecological Naturalness Index (ENI); and the formula used to combine the sub-indices into an overall Natural Character Index (NCI). Chapter 8 also examines contextual information about the participants to determine whether particular characteristics of the participants may have affected their perceptions of natural character.

Chapter 9 contains the final case studies. These apply the QINCCE methodology for a single time period to a section of coastal environment. Two case studies were located on the exposed sandy coast of Bream Bay (Waipu, Ruakaka) and two were located in the relatively sheltered waters of the Bay of Islands (Omarino-Parekura Bay, Orongo Bay-Waikare Inlet).

Chapter 10 reviews the thesis in the context of: the research objectives, its contribution to knowledge; potential practical applications; and future research options. The wider application of the QINCCE methodology (with modification) is discussed.

As this thesis is a compilation of published material, material to be submitted for publication and thesis chapters there is inevitably some repetition, especially in the initial context and literature review sections.

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2 Processes used to develop the quantitative methodology for measuring natural character

2.1 Introduction

The purpose of this chapter is to describe the strategy used to develop the QINCCE (Quantitative Index for measuring the Natural Character of the Coastal Environment) methodology for measuring natural character and its change.

Several chapters include specific methodology that is relevant to the particular chapter. These descriptions of chapter-specific methodology are not repeated in this chapter. Chapter 3 describes the methodology used to develop a comprehensive “first principles” definition of natural character. Following this, Chapter 4 describes the methodology used to: analyse court interpretations of natural character under the Resource Management Act 1991; and compares those interpretations with the definition developed in Chapter 3. Chapter 8 describes the methods used: to obtain natural character perception scores from “informed” participants; to compare those perception scores with scores calculated using a form of the QINCCE methodology; and use the comparison to refine aspects of the QINCCE scoring protocols and the construction of the indices. This chapter also describes the methods used to obtain and analyse participant attribute information in the context of natural character perception. The specific methodology used for the case studies is described in Chapter 9.

2.2 Strategy used to develop the QINCCE methodology

The strategy used to develop the QINCCE methodology was far from linear. Figure 2.1 shows the linkages between the different phases of work leading to the development of the methodology. Table 2.1 sets out each methodology-development “step” (albeit in a more linear fashion than was actually the case), the associated objectives and challenges (and where appropriate responses).

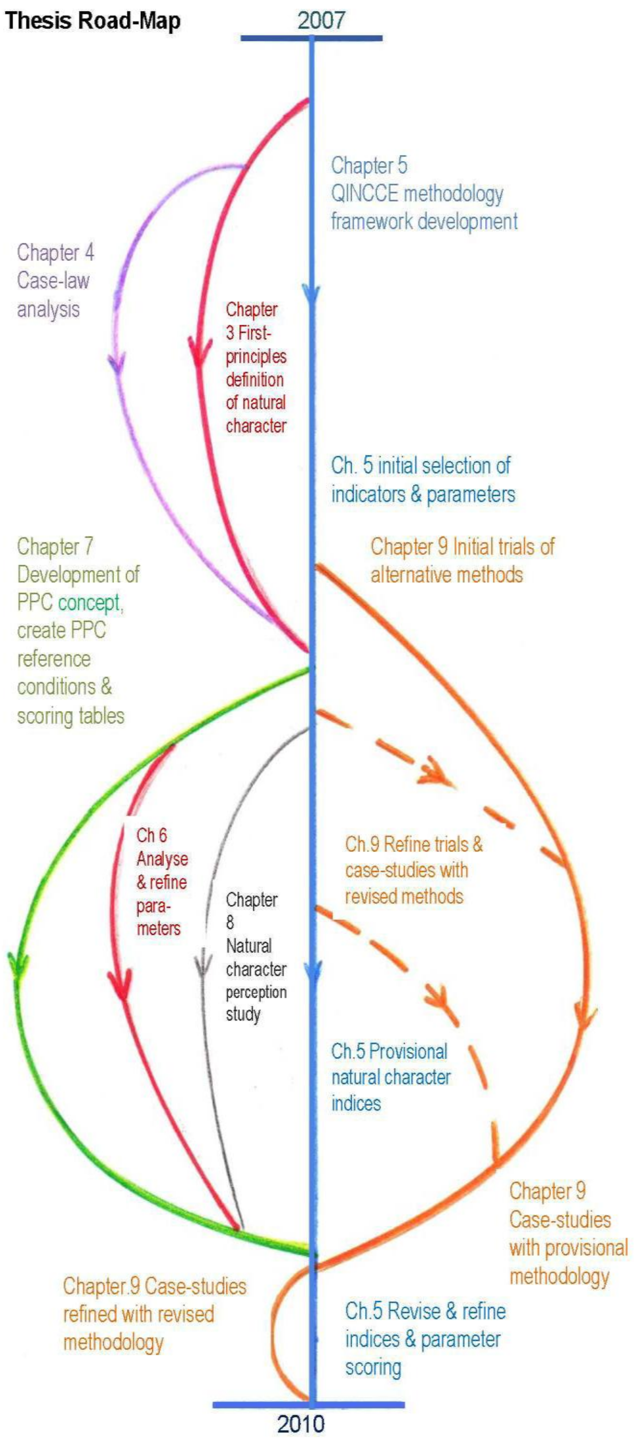

Figure 2. 1: Thesis road-map: relative timing of the different components of the research linked to chapters

Table2. 1: Developing the QINCCE methodology: steps and the associated objectives and challenges

Objectives	**Steps**	**Challenges**
	1. Initial literature review & discussions to identify the most appropriate angle to take on the general topic area.	
Initial overall objective: To determine relative magnitude of reasons for the preservation and loss of natural character (i.e. reasons for the success and failure of the national policy).		No definition of natural character. No agreed methodology for measuring natural character and its change so difficult to assess the magnitude of change. It would be very difficult to obtain sufficient replicates to test the different permutations of reasons across the different types of coastal environment – assessing only a few factors in a limited range of environments and locations could be risky in terms of the robustness of the outcomes.
Revised overall objective: To develop robust objective methodology to measure natural character and its change (so that policy performance could be measured).	2. Review of literature on definitions and interpretations of natural character and equivalent terms. Review literature on perception, landscape preference and recreation experience and determine their relationship to natural character.	
Table 1.1, Objectives 1 & 2	3. Develop a first-principles definition of natural character using criteria designed to address the New Zealand policy and environmental context (Chapter 3).	The thesis by papers approach led to early versions of this paper trying to cover too much subject matter (later addressed by adding extra chapters).
Table 1.1, objective 3	4. Analyse 100 Court decisions that address natural character to determine Court-intended outcomes for natural character, Court interpretations of natural character and section 6(a) of the Resource Management Act.	
Table 1.1, objective 3	5. Compare the definition developed in Step 3 with the	

Objectives	Steps	Challenges
	analysis of case law to check for congruence (Chapter 4).	
Table 1.1, objectives 4, 5 and 6	6. Review of literature on methodologies for: measuring complex natural concepts (e.g. biodiversity); assessing naturalness/natural character; analysing data and reporting results from a range of measures (e.g. using indices. Review of literature relating to potential parameters for measuring components of natural character in terrestrial and aquatic coastal environments. Began preparation of chapters 5 and 6	
Table 1.1, objectives 4, 5	7. Selected the indicators/ associated parameters approach used by OECD and other international monitoring programmes and New Zealand's Ministry for the Environment as the overall methodological approach for measuring natural character.	
Table 1.1, objectives 4, 5	8. Early trials of a variety of indicators/parameters (using the definition to provide a framework for indicator/ parameter selection) and potential measurement approaches.	Tension between measuring parameters (requiring detailed measurement) and being able to evaluate a sufficiently large area so that the methodology could be used for more than very local assessments.
Table 1.1, Objectives 6 & 7	Review of literature on the use of baselines/reference conditions. Review of relevant literature to assist with the construction of baselines for assessing different components of natural character in northern New Zealand. Review of literature to obtain information for constructing scoring tables for measuring progress towards baselines/reference conditions. Prepared chapter 7	There was relatively little information to assist with construction of the scoring tables for measuring progress towards present-potential cover in some systems (chapter 7). There was relatively little information to guide the construction of scoring tables for measuring hydrological and geomorphological impacts
Table 1.1, objectives 4, 5	9. Trials using different approaches for defining units within which natural character	Initial formulaic approach for defining unit boundaries found to be

Objectives	Steps	Challenges
	would be assessed.	unworkable in practice so revised the approach.
Table 1.1, objective 6	9. Develop a provisional analysis framework based on indices.	
Table 1.1, objectives 4, 5 and 6	10. Case studies using provisional parameters & protocols for boundary definition. Boundaries digitised and linked to spreadsheets containing parameter data for some case studies (Chapter 9).	My early tendency to define small units, meant that the budget for digitising was used up faster than expected. The indices and their combination into an overall natural character index were not sufficiently well developed and the case study analysis could not be completed.
Table 1.1, Objectives 6 & 8	11. Further literature review on approaches for combining parameters into indices and combining different sub-indices into an overall index. Decided to use a perception study by informed participants to guide the relative weighting of the sub-indices in an overall index of natural character. Reviewed literature on methods for determining public perception (especially of concepts such as environmental naturalness). Began Chapter 8).	
Table 1.1, Objectives 6, 8 & 9	12. Designed, prepared and implemented a perception study using “informed” participants.	
Table 1.1, Objectives 6, 8 & 9	13. Undertook a comprehensive analysis of the data from the perception study, including comparing this with calculated natural character scores.	Tried to construct a model so as to determine appropriate weightings of the sub-indices in an overall natural character score but this was not possible. This led to a review of the sub-indices, the parameters and scoring systems.
Table 1.1, Objectives 6, 8 & 9	14. Revised and refined the sub-indices, their parameters and the associated scoring systems. Determined how to combine the sub-indices (Chapters 5 & 8).	
Table 1.1, Objective 9	15. Analysed personal attribute data of the perception –study participants to determine	

Objectives	Steps	Challenges
	whether particular attributes affected the scoring in certain situations (Chapter 8).	
Table 1.1, Objective 6	16. Completed case study analysis. The scores were recalculated using new data as appropriate. Digitised boundaries printed with natural character scores (Chapter 9).	As there was no further funding for GIS digitising, the original unit boundaries could not be changed. The ideal would have been to completely revise the case studies making use of all the lessons learnt along the way
Table 1.1, Objectives 4, 5, 6, 7 ,8 and 9	17. Complete chapters on methodology (5,6 7), perception study and its implications (8) and the case studies (9).	
All objectives	18. Complete chapters 1, 2 & 10 and combine into the draft thesis to submit for examination.	
All objectives	19. Receive examiners' reports, oral examination and final revisions.	

2.2 Initial methodology development

Once the comprehensive definition of natural character had been developed (Chapter 3) and compared against court decisions (Chapter 4), a comprehensive review of the literature included evaluations of: potential approaches for measuring the different components of natural character; and alternative approaches for integrating and combining different measures. Criteria specifying the methodology requirements (Table 5.1) were developed and refined as part of the literature review process. It was decided that because it is not possible or practical to measure all aspects of natural character, then key indicators of natural character should be measured. The definition of natural character (Chapter 3) formed the framework for indicator selection (Table 5.2). The basic indicator set was determined relatively early, but was revised and refined as methodology development proceeded.

Early development of the methodology took place over a relatively wide geographical area in Northland, New Zealand. These early trials tested a range of potential approaches identified through the literature review. With a coastline of 3077km, the Northland Region provides a wide range of coastal environment types. The early trials primarily took place on Northland's east coast and included mainland open rocky and soft sediment coasts, harbours and estuaries of different sizes, and islands. Terrestrial, freshwater and marine coastal environments were included. Appendix 1 contains a summary of the locations used for the early methodology development trials.

2.3 Defining units within which natural character would be assessed

Northland Regional Council provided 1:10,000 aerial colour paper prints of much of the eastern Northland coast. These paper prints were set up using a grid on a largely continuous digital aerial image mosaic. This mosaic had been compiled using photography from different councils and it was not possible to identify the date of imagery for a particular section of coast. Higher resolution aerial photography was available for several coastal settlements, including Waipu Cove and Ruakaka in Bream Bay.

The level of natural character can vary considerably within and between different types of coastal environment. Methodology for assessing natural character needed to address this spatial variability through the appropriate delineation of units within which natural character would be assessed. Automatic classification without prior manual definition of units was rejected as discussed in Chapter 5. Options tested for delineating "units" included: a series of "zones" that were largely parallel with the shore; using different unit boundaries for different parameters; and depicting units that had relatively homogeneous levels of natural character. The third approach was selected with a number of iterations to determine the most appropriate combination of factors to use for manually defining these discrete units. The final mix of factors selected is described in Chapter 5.

The boundaries of the units in the case studies were defined (Chapter 9) before this final factor mix was finalised. While in hindsight it may have been better to have amalgamated some units or to have placed the unit boundaries in slightly different locations, the case studies provide an example of a reasonably detailed application of the methodology for unit boundary definition. This is especially so for the Ruakaka and Waipu case studies where high resolution aerial photography was available.

2.4 Selection, refinement and combining of parameters

The selection of the final parameter set and methods to be used for measuring these parameters was a lengthy process. A number of approaches were trialled. An early approach, modelled on the methodology for measuring New Zealand wetland condition (Clarkson et al. 2004), scored 'naturalness' from 0 to 5 for vegetation composition and structure; geomorphology and hydrology, structures and buildings, and proportion of alien species in the canopy. A variant of this used different scoring ranges. This approach was rejected because it did not meet the methodology criteria in Table 5.1.

The second approach was to more tightly prescribe actual parameters by specifying exactly what is being measured. There was also a focus on obtaining numerical data where possible as this was considered more robust for measuring change over time (Chapter 5). A number of potential parameter combinations were trialled. Some parameters went through a number of iterations. While numerical measures were favoured it was clear that some key components affecting natural character could not be directly measured using a single number. Instead these components could be scored either: directly by the use of clearly defined numerical categories; or derived by converting measured data into clearly defined numerical categories.

Alternative approaches were evaluated for measuring the level of naturalness for potential ecological, hydrological and geomorphological parameters. . A priority was to assess naturalness in a way that facilitated comparisons of the levels of natural character present in different types of coastal environment. This required the use of reference conditions (Higgs 2003) (or the equivalent baselines) against which the current level of natural character for different parameters would be assessed. Chapter 7 discusses the development of the *present-potential* reference condition (state that would be present today if humans and the species they brought had not arrived in New Zealand but natural processes had continued) for cover and the hydrological and geomorphological naturalness parameters. Scoring tables used for measuring progress towards the present-potential reference condition were constructed after extensive literature reviews. The literature consulted as part of the preparation of the cover scoring tables addressed vegetation change, ecological succession, patch dynamics, disturbance and relevant ecological succession studies relating to particular environments or types of cover.

A literature review of options for combining and reporting data from different types of parameters led to the construction of natural character sub-indices that could be combined into an overall natural character index (Chapter 5). There was extensive testing of options, especially to determine which parameters should be included in the sub-indices. The selected parameters were termed *core parameters*. In addition to the literature review, trials and case studies (Chapter 9), a perception study using 113 "informed" participants was carried out to refine: the parameter set used for each sub-index, parameter scoring and the combining of the sub-indices into an overall natural character index (Chapter 8).

Some of the potential parameters that still had merit but could not be widely applied (because they were not sufficiently universal and/or required too much work to measure on a widespread basis) became *Tier two* parameters for use only in detailed assessments. As an example, alternative parameters and methods for measuring the extent and condition of pohutukawa along Northland rocky shores were tested. This measure could not be used for all terrestrial coastal environments, and so it was decided that it would be addressed as part of the *Tier-Two* parameter set. The rationale and implementation of the *core* and *Tier-Two* parameters are primarily addressed in Chapters 6 and 7.

While the terrestrial and intertidal parameters are most thoroughly developed, marine environment parameters were also selected. An extensive literature review led to the identification of potential parameters that could be useful for assessing the natural character of marine subtidal environments. These potential parameters were field tested in a selection of shallow, mainly exposed or semi-exposed subtidal environments (<30 metres) in eastern Northland. Comparative exposed rocky coast data were also obtained from the Leigh Marine Reserve, which is on the North Island's east coast to the south of the Northland Region. The purpose of the latter was to obtain reference condition data for several parameters to assist with the construction of scoring tables.

2.5 Case studies

The formal "case study phase" (Chapter 9) occurred at a time when methodology development was well advanced. There were four completed cases studies. Figure 2.2 shows their locations and Appendix 2 contains a summary of their characteristics. Appendix 2 also contains two additional locations where there were insufficient resources for digitising the unit boundaries.

The case studies raised new questions and new perspectives. This led to considerable refinement of the methodology as described in Chapter 9.

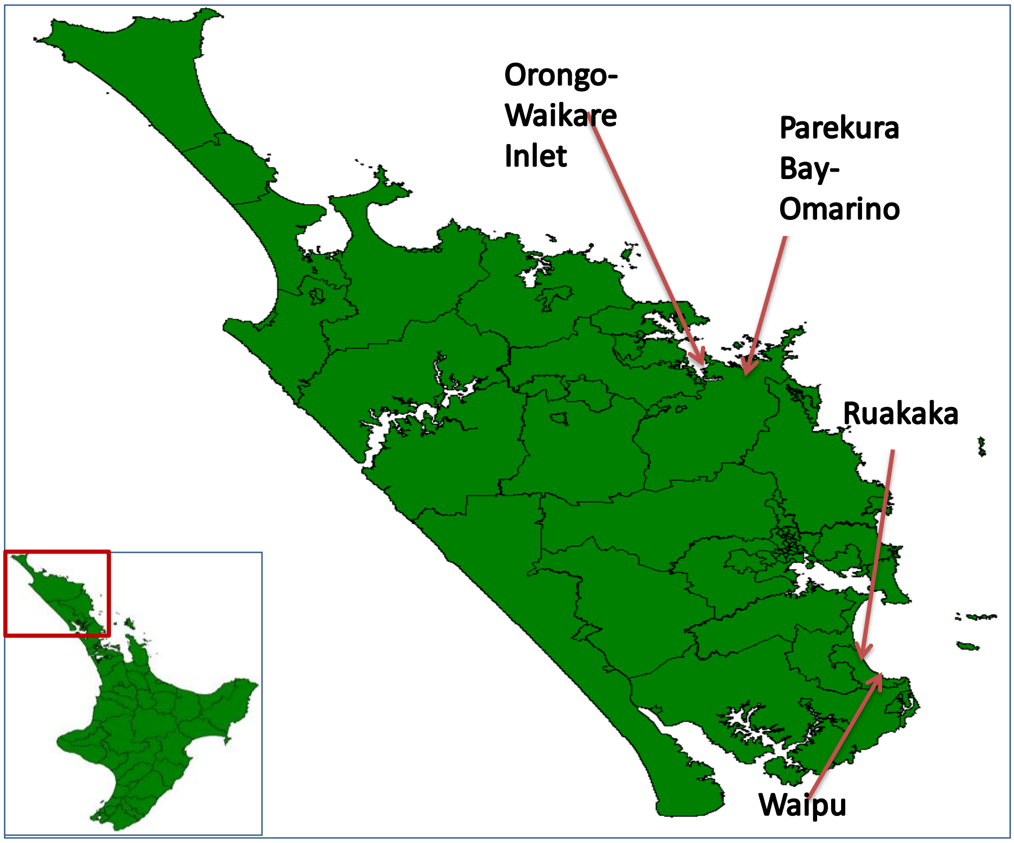

Figure 2.2: Locations of the four Northland case studies used for trialling the natural character measurement methodology

As a consequence of iterative processes of methodology revision, the approach used in the case studies was revised several times. The final iteration of the case studies used in this thesis incorporated the results from reassessing the parameters for each mapped unit to the extent that this was practicable. It was not possible to amend the boundaries of the already digitised units.

A lack of resources precluded the completion of comprehensive marine case studies following methodology development. Suggestions for future methodology refinement and case studies (especially for subtidal environments) are in Chapter 9.

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3 The nature of natural: defining natural character for the New Zealand context

Foreword

This paper has been published and should be cited as:

Froude, V.A.; Rennie, H. G.; Bornman, J.F. 2010. The nature of natural: defining natural character for the New Zealand context. *New Zealand Journal of Ecology 34*(3):332-341.

Several minor amendments have been made to fit the paper into the format of the thesis (changing table numbers to the thesis format, referring to Chapter 4 rather than the thesis in prep., adding section numbers). A postscript addressing the potential impact of the 2010 New Zealand Coastal Policy Statement has been added. As primary author and PhD candidate, Victoria Froude developed the ideas, researched the content, and prepared and revised the text. The contributions of the two other authors were to suggest improvements in the context of their role as supervisors.

Abstract

New Zealand has a long-standing statutory policy goal to preserve the natural character of the coastal environment and various freshwater environments and their margins. In the absence of an authoritative definition, it has not been possible to develop a method to measure natural character and its change, nor the outcomes of the long-standing national policy goal. Here we develop a definition of natural character that is relevant and useful in the New Zealand environmental, cultural and legal/policy context. Literature-derived interpretations of natural character and equivalent concepts are evaluated as to their potential suitability for developing a biophysical definition of natural character. Using a set of carefully designed criteria a subset of interpretations are condensed into a definition of natural character. The application of this definition is qualified following consideration of the literature addressing human perception and experiences of natural character. Appropriate reference conditions and baselines for evaluating natural character in different contexts are discussed.

Keywords: baselines; coastal environment; environmental naturalness; environmental policy; human perception; reference conditions; Resource Management Act

3.1 Introduction

Natural character is a complex concept. This concept, and the equivalent term [environmental] naturalness, is used by a variety of disciplines including conservation biology/ecology, landscape planning and design, environmental management and restoration, resource planning, geography, ethics/philosophy and psychology.

New Zealand has a long-standing statutory policy goal to preserve the natural character of the coastal environment and various freshwater environments and their margins. Although this policy has been incorporated into several statutes, the term ‘natural character’ is not defined. In the absence of an authoritative definition it has not been possible to develop a comprehensive methodology to measure natural character and its change, nor the outcomes of the long-standing national policy goal.

The purpose of this paper is to develop a ‘first principles’ definition of natural character that is relevant and useful in the New Zealand environmental and legal/policy context. Such a definition should be comprehensive, useful for decision-makers, and provide a basis for evaluating the outcomes of the national policy goal.

3.2 Methodology

The first stage in developing a ‘first principles’ definition was the analysis of the New Zealand legislative, policy and environmental contexts. The insights gained from this were used to develop a comprehensive set of criteria against which to evaluate interpretations of other authors.

A variety of sources (including online databases) were searched to find papers and books that addressed natural character and equivalent concepts. The need to conduct a search on equivalent concepts was because the term 'natural character' is not widely used in the published literature outside the New Zealand context. Searches on terms such as 'natural' and 'naturalness' were qualified to address the usages of these terms in the context of disciplines such as environmental management, biological conservation and geography.

Although the New Zealand policy applies to a limited range of ecosystems, no such limitations were placed on the literature analysis. Most of the publications reviewed either: addressed natural character and equivalent concepts without reference to particular ecosystems, or focused on terrestrial ecosystems. Relatively few papers addressed the concept of natural character or environmental naturalness for marine ecosystems.

Disciplines represented in relevant publications included conservation biology/ecology, landscape planning and design, environmental management and restoration, resource planning, forestry, geography, ethics, philosophy and psychology. Some publications focus on human perceptions of natural character or environmental naturalness and typically do not define natural character.

A suite of interpretations derived from the literature analysis were assessed against a set of carefully developed criteria. As our purpose was to develop the most appropriate definition for the New Zealand context, we sought a relatively broad definition. This was achieved by combining interpretations as appropriate while excluding those that did not meet the criteria.

3.3 Towards developing a definition of natural character

3.3.1 The purpose

Definitions or interpretations of natural character, environmental naturalness, or equivalent concepts are usually developed for a specific purpose. These purposes have included:

- Evaluating the utility of naturalness as a biological conservation objective (e.g. Angermeier 2000; Siipi 2004)

- Using naturalness as one of a suite of criteria for biological conservation (e.g. Margules 1986)
- Evaluating whether it is a useful concept for distinguishing/selecting between environmental/ecological management strategies (e.g. Siipi 2004)
- Contributing to a framework for assessing visual quality and ultimately measuring the effect of landscape change on visual character (e.g. Tveit et al. 2006)
- Providing guidance for inventories and Resource Management Act 1991 decision making (e.g. McRae et al. 2004)

The purpose of the definition being developed in this paper is to contribute to the analysis of policy implementation, including the measurement of natural character and its change.

3.3.2 New Zealand legislative and policy context

New Zealand's long-standing statutory policy goal to preserve the natural character of the coastal environment, riparian and various freshwater environments is in the planning/development control and protected areas legislation. This policy was developed in the early 1970s as part of the response by the then government to widespread public concern about the rapid rate of coastal and lake-margin development (Minister of Works and Development 1974). It was first included in the planning/development control legislation via a 1973 amendment to the Town and Country Planning Act 1953. This amendment added a new ‘matters of national importance’ section, which included the preservation of the natural character of the coastal environment and the margins of lakes and rivers.

This matter of national importance was transferred into the Town and Country Planning Act 1977 and subsequently expanded in the Resource Management Act 1991 to include wetlands, and the bodies of rivers and lakes. While the terrestrial inland boundary of the coastal environment is not defined in the Resource Management Act, the outer boundary is the 12-nautical-mile limit of the territorial sea.

The policy goal to preserve the natural character of the coastal environment and the margins of lakes and rivers was introduced into the protected areas legislation as part of one of the three purposes of the new Reserves Act 1977. This purpose remains unchanged. Initially, implementation of the natural character policy via the planning and protected area legislation was strongly linked by a series of mechanisms, including:

- An interagency committee
- Potential-coastal-reserves surveys of coastal counties and boroughs
- Formal communication of survey results to councils for them to address in their planning documents
- Allocation of government funding for the Crown to purchase coastal reserves

The public concerns that had initially led to government action on natural character largely focused on aesthetic appreciation and recreational experiences of natural character (Maplesden & Boffa Miskell 2000), but over time the public has become increasingly concerned about the conservation of nature. This has been reflected in the expanded scope of judicial interpretations of natural character adopted in decisions made under the Resource Management Act.

Several other Western countries have also incorporated the protection of environmental naturalness into their legislation. Federal legislation in the USA (e.g. Wilderness Act 1964) provides the context for much of the discussion about naturalness within biological conservation and ecological literature (e.g. Landres et al. 1998; Czech 2004).

Cultures vary in their understanding and recognition of environmental naturalness. Economically developed nations that have been colonised relatively recently by Western culture tend to have shown the strongest desire to protect environmental naturalness (Dunlap 1999). The loss of indigenous species and ecosystems proceeded extremely rapidly in these nations after colonisation and that may have been an important trigger.

Probably the most extreme example was New Zealand, which during the second half of the 19th century experienced one of the most rapid periods of indigenous forest clearance anywhere in the world (Tong & Cox 2000). At its peak in the decade between 1890 and 1900 forest clearance removed 27% (3.5 million ha) of New Zealand's forest. There are eloquent accounts (e.g. Froude 1886) of the extensive clearing and burning of magnificent lowland forest during this time so that the settlers could plant introduced pasture grasses for grazing by introduced livestock.

3.3.3 New Zealand environmental context

New Zealand is unique as an isolated, long, narrow, mountainous archipelago extending between 29 and 52 degrees latitude in the South Pacific Ocean. It lies within the tectonically active 'Pacific Ring-of-Fire' and intercepts the Southern Hemisphere westerly wind zone. Accordingly, parts of New Zealand have frequent and sometimes severe natural disturbance compared with that in stable continental environments.

New Zealand has only been settled by humans for the last 730 years (Wilmshurst et al. 2008). Settlement was initially by people of Polynesian origin, and from the 1800s predominantly by those of European/Caucasian ethnicity (King 2003).

The many millions of years of isolation from other land masses resulted in a unique and vulnerable biota. After the extinction of dinosaurs New Zealand did not follow the rest of the world into the 'Age of Mammals' but instead entered the 'Age of Birds' (Taylor & Smith 1997). Many bird species evolved unique life forms, often losing the power of flight and feeding on the ground in the absence of terrestrial predators. The only terrestrial mammals at the time of human settlement were three species of bat (one now extinct), two of which also evolved to feed extensively on the ground (Wilson 2003). These ground-based habits of many indigenous bird species made them highly vulnerable to human hunting, and subsequently to introduced mammalian predators.

Before human arrival there was a very high level of endemism in both plant and animal species, with 70% of land and freshwater birds and 85% of flowering plant species being endemic. Since human settlement there have been many species extinctions, particularly of endemic species of fauna including all species of the ratite moa. About 46% of New Zealand bird species present before human arrival have become extinct (Taylor & Smith 1997). Today New Zealand's level of threatened species is rated among the highest in the world (Hitchmough et al. 2007; Ministry for the Environment 2007a). Introduced species have had a major impact on the remaining indigenous terrestrial and freshwater biota and ecosystems.

Before human arrival, about 78% of New Zealand was forested. Today, indigenous forest cover is 23%, with much of that remaining being in steep mountainous country. Farmland now makes up 52% of the country, which is much higher than the world average of 37% (Tong & Cox 2000). Nationally, 10% of wetlands present before the arrival of humans remain. In the North Island this is reduced to 4.9% (Ministry for the Environment 2007a).

The natural character of many fresh and estuarine waters has been lost or degraded by drainage, construction of flood control channels and stopbanks, removal of riparian vegetation, point and non-point discharges.

Approximately one-third of New Zealand lakes have poor water quality, with 13% of monitored lakes being extremely degraded and commonly subject to algal blooms (Ministry for the Environment 2007a, b). Nutrient (nitrogen and phosphorus) levels in lakes with pastoral catchments are 2–6 times higher than in lakes with naturally vegetated catchments. Water clarity of lakes in pastoral catchments is one-fifth that of lakes in natural catchments (Ministry for the Environment 2007b).

While New Zealand marine environments are relatively healthy by international standards, approximately 30% are disturbed by human activities (Ministry for the Environment 2007a). Large-scale commercial fishing removes large numbers of organisms, destroys marine habitats, and disrupts marine food chains (Ministry for the Environment 2007a). Ships have introduced new species that have had, or are likely to have, an adverse impact on marine ecosystems.

Considerable areas of sheltered coastal margins have been modified by human activities such as land drainage, causeway construction, seawalls, reclamation and other development. Many nearshore marine environments have been affected by excessive nutrients and increased levels of sediment derived from human land use.

In spite of all this environmental damage, relatively intact areas remain, albeit many in more mountainous areas and without much of their original fauna. Few intact areas remain in lowland and coastal environments, except for some offshore islands and the most remote parts of mainland New Zealand.

3.3.4 Criteria for assessing literature-derived interpretations of natural character

From our analysis of the New Zealand context we developed a set of criteria for assessing literature-derived interpretations of natural character (Table 3.1). Each interpretation of naturalness derived from the literature review was then assessed against each criterion to qualitatively assess the extent to which the criterion was met.

Table 3.1: Criteria for evaluating possible interpretations of naturalness

Criteria	Rationale for choice of each criterion
1. Applies across the full spectrum of environments from pristine wilderness to the highly modified	The New Zealand national policy to protect natural character applies to the coastal environment, wetlands, lakes and rivers and their margins. These exist across a broad spectrum of environmental conditions ranging from relatively pristine at one end to highly-modified (by industrialisation and other development) at the other. In the New Zealand context a definition of natural character needs to cover the full spectrum of environmental conditions.
2. Addresses the effects of human structures and activities	Much of the original impetus in the early 1970s for the development of policy to preserve the natural character of the coastal environment and margins of lakes and rivers was a response to coastal and lake-margin development, including structures. A definition of natural character for New Zealand should address the effects of human structures and activities.
3. Can address ecological	New Zealand’s long history of isolation from other

Criteria	Rationale for choice of each criterion
naturalness in the New Zealand context	land masses led to the evolution of a unique biota and many unique ecosystems. As the last major land mass to be settled by humans, New Zealand saw many of the dramatic changes (species and ecosystem loss, ecosystem degradation) occurring over a relatively short timespan. In addition its terrestrial and freshwater biota and ecosystems have been highly vulnerable to the impacts of introduced species. A definition of natural character for New Zealand would acknowledge that native species are more natural than introduced species. It would also acknowledge that the more natural ecosystems are those that more closely resemble what would have occurred if humans and their agents (introduced species) had not arrived.
4. Can apply to terrestrial, freshwater and marine environments	The New Zealand legislation on natural character applies to terrestrial, freshwater and marine environments, although not all ecosystems within these environments are covered by the policy. In marine environments, the national policy applies from mean high water springs to the 12-nautical-mile territorial sea boundary. In terrestrial environments, it applies to the undefined terrestrial 'coastal environment' and the 'margins' of lakes and rivers.
5. Can be used in a meaningful way to measure progress in ecological restoration	Extensive areas of lowland and coastal terrestrial and freshwater ecosystems in New Zealand have been destroyed, and much of what remains has been seriously degraded. Ecological restoration is encouraged by the New Zealand Coastal Policy Statement (Minister of Conservation 1994). The outcomes of active restoration programmes should be considered positively in a natural character definition for the New Zealand context.
6. Provides for the use of reference markers to give context	Natural character is not an absolute concept. As such it is helpful to use reference conditions against which change can be measured. A definition of natural character in the New Zealand context would provide for the use of reference conditions and baselines as appropriate.

3.4 Interpretations of natural character

This section describes nine interpretations of natural character/environmental naturalness that have been derived from the literature. These interpretations are largely based on biophysical attributes. In most cases an author used or advocated a single interpretation, although several authors (Siipi 2004; Ridder 2007a) compared interpretations.

Each interpretation is discussed individually and assessed against the six criteria in Table 1. This is followed by a synthesis that draws out the key elements to include in a proposed definition of natural character.

3.4.1 Interpretation 1: Naturalness as that which is part of nature

This interpretation excludes human culture's activities and constructions. It has been most extensively discussed in Western cultures, especially those populated by the English Diaspora (Dunlap 1999).

While some ecology authors argue that because humans have evolved naturally, humans and all human activities are natural (Comer 1997; Haila 1997), others argue that if humans and all their activities are natural then the concept of 'naturalness' has no meaning (e.g. Hunter 1996; Siipi 2004). Anderson (1991) and Angermeier (2000) both argued that human activities are unnatural because of the use of technology. Angermeier (2000) observed that human culture and technology have transformed nature and overcome humanity's genetic limitations, resulting in technology-driven changes to the environment that are often more rapid and extensive than natural ecological changes.

Holmes (1995) distinguished between spontaneous nature and deliberated or intended culture. He criticised those that describe humans and their actions as part of nature for not recognising that humans have significantly evolved out from nature and its processes. Holmes observed that while human historical origins were natural, humans now could no longer be considered so.

Klein (2000) observed that in Western environmental ethics human beings are separated from nature and that humankind has a central position within the natural world. This central position makes humans either indifferent to nature (negative anthropocentric) or responsible for nature (positive anthropocentric).

Maplesden and Boffa Miskell (2000), in their analysis of the development of the concept of natural character in New Zealand law and policy, concluded that the primary components that underpin natural character are natural processes, natural elements, and natural patterns. Various New Zealand court decisions support her analysis. For example the Environment Court in *Harrison v Tasman District Council* (1994) states: ‘the word *natural* is a word indicating a product of nature…as opposed to man-made structures, roads, machinery etc.’

McRae et al. (2004) defined natural character as derived only from physical and biological elements, patterns, and/or processes of nature indigenous to the environment being considered. The level of natural character within an area has also been defined as being dependent on both the extent to which natural elements, patterns and processes occur and the nature and extent of modifications to ecosystems and landscapes (Boffa Miskell 2002).

Interpretation 1 addresses criteria 1, 3, and 4 in Table 3.1, but it is not sufficiently comprehensive to address adequately criteria 2, 5 and 6.

3.4.2 Interpretation 2: Naturalness includes humans and their activities

Many traditional indigenous cultures do not recognise a clear distinction between humans and nature. The ‘world view’ of New Zealand Māori is that everything in the universe (both inanimate and animate) has its own genealogy and that all are ultimately linked via the gods to Rangi (the male principle or ‘sky-father’) and Papa (the female principle or ‘earth-mother’) (Roberts et al. 1995). Humans have a central position within the natural world but have to respect the life-force of all natural things and beings (Klein 2000). In traditional Māori society complex rules were used to manage the relationships between components of the environment, and compliance was enforced primarily by fear of divine retribution or confiscation of resources by humans. Roberts et al. (1995) describe the Māori environmental ethic as one of conservation for human use where rāhui (restrictions that set aside an area and prohibit the harvesting of resources) are used to ensure resource sustainability for this use and not for the intrinsic values of the resources concerned.

This ‘world view’ did not prevent major losses of nature. For example, the arrival of the first humans and the Polynesian dog and rat in south-east New Zealand was followed by extinctions of many bird species and three species of frog and several lizards (Hamel et al. 2003). Throughout New Zealand 34 species (including all species of moa megafauna) out of a total of 93 endemic land bird species became extinct before the arrival of Europeans (Taylor & Smith 1997). There was widespread loss of eastern South Island forest and scrub vegetation (McGlone et al. 2003) and heavy exploitation of fisheries such as Northland snapper and various shellfish beds (Flannery 1994).

There are some Western belief systems or paradigms that do not appear to separate humans from nature. One example is the Gaia hypothesis (Lovelock 1988, 2000), which proposes a 'live earth' where the climate and chemical composition of Earth's atmosphere are kept in homeostasis until an internal contradiction or external force leads to a sudden jump to a new stable state. In this hypothesis humans are just another species, albeit one that can destroy the balance and may be destroyed as a result of the resulting changes. Lovelock (2000) does however observe that humankind is remarkable because it has created itself as an 'entirely new entity' using a combination of attributes (including brain size, faculty of speech, use of tools, and socialisation).

Another Western paradigm is that of 'new ecology', which includes humans as part of complex and changeable biophysical systems. Under this paradigm there is no benchmark of stability derived from the non-human or natural world, human alterations of apparently stable ecosystems are not necessarily bad, and 'conservation' should proceed by way of little or no interference (Castree 2005). 'New ecology' is not an appropriate paradigm for New Zealand environmental management as it would lead to the loss of much indigenous biota and the loss and/or degradation of many ecosystems dominated by indigenous species.

Interpretation 2 does not address criteria 3, 5 and 6 from Table 3.1 and it is unclear how it would support criteria 1 and 2. Including this second interpretation in a definition of natural character would result in an ambiguous definition. With such a definition it would not be possible to measure progress towards implementing the natural character policy goal that is in New Zealand legislation.

3.4.3 Interpretation 3: Naturalness as a contrast to ‘artifactuality’

In this interpretation naturalness is contrasted with artefacts. Siipi (2004) defined an ‘artefact’ as something that is intentionally brought into existence by humans to have specific properties that have some designed functions. Having a designed function implies that the entity (‘artefact’) can be used for fulfilling human desires or purposes. This incorporates the wide array of human constructions including walls, buildings, roads and rail lines, transmission networks, vessels and vehicles. ‘Naturalness as a contrast to ‘artifactuality’ is an interpretation that is implied by a number of authors (e.g. Richmond & Froude 1998; Boffa Miskell 2002).

Siipi applied her definition of an ‘artefact’ to biotic elements. Some biotic elements (e.g. gardens and modern commercial fields) were defined as biological ‘artefacts’ because they had been brought into existence through species modifications and they had designed functions such as food production.

Interpretation 3 may be implicitly included in some human societal perceptions of naturalness. In a study of public perception of certain land uses in the Coromandel Peninsula, New Zealand, Fairweather and Swaffield (1999) found that a large sector of their sample group considered naturalness was most strongly diminished by the presence of constructions representing human settlement. The other large sector considered that naturalness was most strongly diminished by the presence of a particular type of ‘biological artefact’ – plantations of introduced pine trees. This second group did not react as strongly to the other common ‘biological artefact’ present on the Peninsula – pastoral farming using other introduced species.

Interpretation 3 addresses criteria 1, 2 and 4 in Table 3.1. It does not adequately address criteria 3, 5 or 6. This is because it does not address the attributes of areas that are not ‘artefacts’ and it does not provide a way to measure progress in ecological restoration.

3.4.4 Interpretation 4: Naturalness as historical independence from human actions

In this interpretation (which is one of Siipi's (2004) two preferred 'definitions' of naturalness) the most natural areas are those where there has been little or no human activity. These most natural areas would closely resemble the biological composition and structure of prehuman reference conditions.

The degree of independence from historical human actions can be difficult to measure unless either the detailed human history of an area is known or it can be determined from the current state. Landres et al. (1999) questioned the feasibility of distinguishing between certain historical human-induced versus natural disturbances, particularly in areas where humans have been settled for a long time. They observed that for parts of the USA it is difficult to distinguish between the outcomes of historical forest fires caused by humans and those resulting from lightning strikes.

Since New Zealand was settled relatively recently, it is generally more practical to identify the prehuman state of New Zealand terrestrial environments and the subsequent changes than for other land masses. The same is theoretically true for the marine environment. Even so, basing naturalness assessments on historical independence from human actions is likely to be difficult to implement.

Interpretation 4 addresses criteria 1, 4 and 6 in Table 3.1. It does not address criterion 5 because this interpretation implies that past human restoration activities intended to repair damage from earlier human activities has made the affected areas less natural. Interpretation 4 only partly addresses criterion 3 because it implies that human actions to remove or control introduced plant and animal pests, and especially the past intensive management that has resulted in pest-free areas (e.g. Kapiti Island), has made such areas less natural. This interpretation only partly addresses criterion 2 because it focuses on historical independence from human actions.

3.4.5 Interpretation 5: Naturalness is where ecosystem processes occur without human intervention

This interpretation focuses on the lack of present and future human intervention without particular regard to what has happened in the past. In so doing it focuses on processes rather than outcomes. There are several variations on this theme.

The first is Ridder's (2007a) preferred definition of 'naturalness'. He considered naturalness to be where processes are in harmony with nature and there is a lack of human intervention. Ridder did not specifically address the outcomes of these processes. The primary focus was the concept of leaving nature alone. In a similar vein, Olwig (1984) questioned the naturalness of the intensive management needed to maintain the Jutland heaths in Denmark once they were no longer being farmed.

The second variation is the definition of naturalness by Schnitzler et al. (2008). They defined naturalness to be spontaneous natural ecosystem processes without human input and where no specific outcomes are sought and no species or habitats are favoured. All ecosystems are considered to possess the same intrinsic value when left alone to develop spontaneously, regardless of the start point. There is no hierarchy of outcomes and certainly no reference to historical accuracy.

Interpretation 5 does not acknowledge the damaging impacts of the many introduced species on New Zealand's unique and vulnerable species and ecosystems. Naturalised introduced species continue to threaten many indigenous species and ecosystems. Areas at particular risk from plant pests include wetlands, sand dune communities, rivers and lakes, coastal margins, riparian margins, and coastal and lowland remnant vegetation (Froude 2002). Without ongoing human management, introduced animal pest species threaten almost all New Zealand terrestrial and freshwater ecosystems and many plant and animal species. Present and future management of naturalised plant and animal pest species is essential for the protection of New Zealand's ecological natural character.

Some New Zealand ecosystems have nearly been lost because of past human actions, but ironically human intervention is now needed to retain what remains.

For example, burning by humans has largely removed the fire-sensitive but drought-tolerant woody vegetation of the south-eastern South Island and resulted in its replacement by *Chionochloa* tussock grasslands (McGlone 2001). Given the present-day risk of fire it is likely that human intervention will be needed to protect and maintain a few examples of this possibly globally unique woody vegetation (McGlone 2001).

Interpretation 5 does not address criteria 3, 5 or 6 in Table 3.1 and only partly addresses criteria 1 and 2.

3.4.6 Interpretation 6: Naturalness that includes ecologically harmonious human influence or actions

Povilitis (2002) expressed concern that interpretations of naturalness that focused on an absence of human intervention could work against ecological restoration activities. He suggested that ecologically harmonious human influences (such as restoring natural hydrological regimes) could be included within the concept of ‘natural’. This would mean that an area that has been subject to intensive ecological restoration would be considered as natural as an area with the same ecological condition that has not been subject to intensive management. Povilitis observed that this would require the formulation of ecologically based rules to prevent adverse human impacts from being construed as ‘natural’.

Interpretation 6 addresses criteria 1, 4 and 5 in Table 3.1. While interpretation 6 does not adequately address criteria 2, 3 or 6, it does not contradict these criteria.

3.4.7 Interpretation 7: Naturalness only includes humans if they are in a closed system

Margules and Usher’s (1981) definition of a natural ecosystem included humans only if those humans were totally dependent on and limited by, that ecosystem. In this closed system there would be no import or export of people, food or materials.

Today very few, if any, indigenous people live in closed systems. The history of human occupation in New Zealand indicates that such a state potentially occurred for only a very limited time. The first humans arrived in New Zealand in AD 1280. This was followed by rapid environmental change including megafauna extinctions, marine mammal decline and deforestation (Wilmshurst et al. 2008). For a short period of time resource shortages and environmental degradation caused by Māori may have led to a semi-stable ecological state before the arrivals of the first Europeans in the 16th century. Since the arrivals of those first Europeans, Māori have not lived in a closed system.

Interpretation 7 does not adequately address criteria 2, 3, 5 or 6 in Table 3.1 and is not a relevant concept for the development of a definition of natural character for the New Zealand context.

3.4.8 Interpretation 8: Naturalness as possession of features and properties found in an 'ideal' natural ecosystem

Under this interpretation the most natural areas would be those whose features and properties most closely match an 'ideal' natural ecosystem. According to Siipi (2004) an 'ideal' natural ecosystem could be either an imaginary, totally natural ecosystem or real present-day examples that are closest to the 'ideal'.

The use of the term 'ideal' means that there is a level of ambiguity as to how the interpretation would be applied in particular circumstances. 'Ideal' could mean how New Zealand would have been today had humans not arrived. This meaning of 'ideal' would include species of plants and animals that have become extinct since human arrival. A good approximation of 'ideal vegetation' is 'potential vegetation', which is the vegetation that could be expected to be present in an area assuming physical-change events such as volcanic eruptions had occurred but humans and their agents (introduced species) had not arrived (Leathwick et al. 2003).

Interpretation 8 generally addresses criteria 1, 3, 4, 5 and 6 in Table 3.1. There is a level of uncertainty here as the term 'ideal' could be interpreted in different ways. Criterion 2 does not appear to be adequately addressed by this interpretation.

3.4.9 Interpretation 9: Naturalness as similarity of biotic structure and composition, and physical/ecological processes compared with historical benchmarks

This differs from interpretation 8 by the use of real, usually historical, benchmarks. Several authors address this concept although in different ways.

The Department of Conservation (2001a, b) defined natural character as ecological condition. In particular, the natural character of an area represents the degree to which the original prehuman condition of an ecosystem remains. Under this definition the most modified areas have the least natural character. Natural character in this context is measured by quantifying the following five pressures:

- Amount of removal of biota through, for example, hunting, harvest, land clearance, fishing
- The level of consumptive pressure on native biota represented by the variety and abundance of introduced pests
- The level of competition pressure on native plants as indicated by the percentage cover of introduced plants
- The intensity of disturbance as indicated by the amount of change to, for example, natural hydrology, nutrients, substrate, light and temperature regimes
- The change in the natural character of the surrounding landscape associated with ecosystem fragmentation, loss of connectivity, and pests

Other authors tend to focus more directly on the state of the areas being assessed. For example, Lamb and Purcell (1990) used the degree to which vegetation structure and floristic composition were ‘typical’ as their representation of ecological naturalness. Purcell and Lamb (1998) considered that naturalness should encompass both vegetation parameters (vegetation type and foliar density) and the amount and type of human-induced change to that vegetation (primarily weed invasion and grazing by domestic animals). In practice they assessed vegetation type, vegetation structural integrity, and foliar density.

Ridder's (2007a) less preferred definition of naturalness was that it is a property of species and ecosystems found in an area prior to specified historical benchmarks. He used industrialisation as this benchmark, while at the same time arguing that the industrialisation benchmark was arbitrary because humans affected ecosystems before this time.

Interpretation 9 does not distinguish between the naturalness of preserved versus restored ecosystems that have the same structure, composition, and processes compared with the chosen benchmark. As such it can be an appropriate objective for ecological restoration programmes where historical fidelity (as described by Higgs 2003) is sought.

Interpretation 9 addresses criteria 1, 3, 4, 5, and 6 in Table 3.1. Criterion 2 does not appear to be adequately addressed by this interpretation.

3.4.10 Key elements for a definition of natural character

As shown by Table 3.2 none of the nine interpretations fully addressed all of the six criteria in Table 3.1. The interpretations that met most of the Table 3.1 criteria do, however, provide a basis for a definition of natural character. Interpretations 8 and 9 both addressed all except criterion 2. Criterion 2 was best addressed by interpretation 3, which also addressed criteria 1 and 4.

Table 3.2: Summary of criteria in Table 3.1 met by each interpretation of naturalness

Interpretation	Criterion 1	2	3	4	5	6
1. Naturalness as that which is part of nature	Y	Pt	Y	Y	Pt	Pt
2. Naturalness includes humans and their activities	?	?	X	?	X	X
3. Naturalness as a contrast to 'artifactuality'	Y	Y	X	Y	X	X
4. Naturalness as historical independence from human actions	Y	Pt	Pt	Y	X	?
5. Naturalness is where ecosystem processes occur without human intervention	Pt	Pt	X	?	X	X
6. Naturalness that includes ecologically harmonious human influence or actions	Y	X	X	Y	Y	X
7. Naturalness only includes humans if they are in a closed system	?	X	X	?	X	X
8. Naturalness as possession of features and properties found in an 'ideal' natural ecosystem	Y	X	Y	Y	Y	Y
9. Naturalness as similarity of biotic structure and composition, and physical/ecological processes compared with historical benchmarks	Y	X	Y	Y	Y	Y

Y=criterion met; X=criterion not met; Pt=criterion only partly met; ?=uncertain how criterion is addressed.

As indicated by interpretations 8 and 9, the selection of appropriate baselines or reference conditions is an important part of a proposed definition of natural character. This is discussed further in the next section.

Another important concept is that of a continuum. Natural character is generally viewed as occurring on a continuum (Richmond & Froude 1998; Angermeier 2000; Maplesden & Boffa Miskell 2000; Boffa Miskell 2002; Czech 2004;

Machado 2004). As long as some components of the biological system remain, there is still some naturalness present (Siipi 2004). Siipi (2004) suggested that, in the context of biological conservation, naturalness be considered as existing along a gradient made up of several independent factors. The most natural entities (e.g. remote unexplored areas) would be natural in all of the interpretations of naturalness. In contrast, while the most unnatural environments would be unnatural in a variety of ways, some naturalness exists as long as some biotic elements remain.

3.5 Reference conditions and baselines for evaluating naturalness

A variety of information sources can be used to compile reference conditions (Higgs 2003) that have historical fidelity for a particular area. The identification of local reference conditions can greatly assist the development of ecological restoration goals that provide for natural temporal and spatial variability. In contrast, a baseline is like a fixed-point 'snapshot'.

A number of authors have promoted a prehuman baseline against which naturalness should be assessed (e.g. Anderson 1991; Hunter 1996; Angermeier 2000; Stephens et al. 2002). It can be difficult to develop a prehuman baseline for areas where humans have been present for many thousands of years (Usher 1986)). It may be possible to identify a partial prehuman baseline for naturalness in recently settled lands such as New Zealand. However, while the broad prehuman New Zealand vegetation patterns are known, the importance of natural disturbance could make the application of these patterns at the local level more complex. Faunal extinctions and changes in distribution and abundance would make it difficult to identify locality-specific prehuman faunal baselines.

To overcome such problems, Czech (2004) proposed a pre-industrialisation benchmark for naturalness. This was based on the assumption that the industrialisation of the 18th and 19th centuries substantially increased economic production and consumption to a level several orders of magnitude higher than pre-industrial levels. For example, Oliver et al. (2002) used a pre-industrialisation benchmark of 1750 for evaluating vegetation condition in Australia, an approach criticised by Ridder (2007a), given the known significant impact of humans on the pre-industrialised Australian environment. Similarly, pre-industrial Māori in NewZealand had a major impact on New Zealand biota and ecosystems.

This pre-industrialisation, pre-Western colonisation perspective seems to be most common where authors are addressing larger continental land masses. In these cases the long period of human occupation has made it difficult to identify the impacts of early human activity (e.g. Comer 1997). Several authors have questioned the extent to which the impacts of pre-industrial indigenous people could be considered natural (Landres et al. 1998; Ridder 2007a; Pinnegar & Engelhard 2008).

Spatial scale is important when considering baselines and reference conditions. Natural character or naturalness can be evaluated at many scales. At the level of a biological population there may be a high level of naturalness (unless its structure has been significantly modified by human activities). At the biological community level naturalness may be reduced by introduced species browsing, preying on and replacing indigenous species. Naturalness may be further reduced at the catchment or watershed scale due to widespread removal of natural habitats and their replacement by agricultural systems that use introduced species, and human settlements.

To address the problems of variable pre-industrialisation human impacts in different locations, Landres et al. (1998) suggested that a variable context-dependent baseline could be used. In areas where there has been a long history of human modification and historical baselines are not available, present-day least-disturbed communities may provide appropriate reference conditions.

A ‘good’, present-day example is often used to identify goals for ecological restoration, especially where the full prehuman or pre-industrialisation assemblage of species is no longer available because of extinctions and/or current conditions are hostile for the survival of some species at the site in question. Both situations are common in New Zealand because many bird species have become extinct (Taylor & Smith 1997) and many remaining species of fauna cannot survive on mainland New Zealand because of predation by alien species.

3.5.1 Appropriate reference conditions and baselines for New Zealand

At broad scales, appropriate terrestrial vegetation reference conditions could be based on the potential vegetation for different land environments as described in Leathwick et al. (2003). In some locations the underlying available physical (especially soils) and climatic data have limited the depiction of more detailed land environments and, by implication, the description of potential vegetation. Where more detail is required the development of reference conditions could draw more strongly on good quality present-day examples and historical information sources (including anecdotal reports, pollen profiles and archaeological remains) where these are available.

The development of appropriate terrestrial faunal reference conditions poses a particular challenge, as the concept of potential vegetation cannot be directly translated to terrestrial fauna. A major reason for this is the large number of extinctions of ecologically significant fauna (including all species of moa) since human arrival. In contrast, New Zealand’s major habitat-forming plant species have not become extinct. Faunal reference conditions that exclude extinct species are likely to be most useful for ecological restoration purposes.

In the marine environment both plant and animal species can be habitat-forming, and many mobile species are harvested by humans. As with terrestrial environments, a variety of types of information (such as those described by Pinnegar & Engelhard 2008) could be used to construct prehuman or historical marine reference conditions. Prehuman reference conditions are most appropriate, given the major impacts of even low-technology harvesting on marine populations (Flannery 1994; Hamel et al. 2003; Pinnegar & Engelhard 2008).

Although a 20-class New Zealand Marine Environment Classification (MEC) has been developed for the New Zealand EEZ and the Hauraki Gulf (Snelder et al. 2005), currently it seems that the MEC could have only a limited role in the determination of appropriate reference conditions. This is because only 20 classes are used to cover the entire EEZ, some important variables have not been used to develop the classification thus far, and potential biotic descriptions (equivalent to those accompanying the Land Environments of New Zealand; e.g. Leathwick et al. 2003) are not yet available.

3.6 Human perceptions and experiences of natural character

Human perceptions of naturalness or natural character vary considerably. In contrast to the preceding nine interpretations of naturalness, the next three directly address human perceptions.

3.6.1 Naturalness as closeness to a perceived natural state

The perceived level of naturalness in an area depends on a variety of factors, including matters relating to the perceiver(s) rather than just the site itself. Therefore, perceived naturalness is context dependent. What is ‘natural’ in an urban setting would not necessarily be considered ‘natural’ in a remote setting (Tveit et al. 2006). Factors affecting landscape perception include familiarity and past experiences of the same or similar areas, mood, expectations and intentions, activity (e.g. work, leisure), social setting and socio-cultural aspects (Gobster et al. 2007).

In their assessment of public perceptions of naturalness in Coromandel, New Zealand, Fairweather and Swaffield (1999) found that while there was reasonable consistency in landscapes that participants identified as ‘natural’ (native vegetation), there were differences between the landscapes they considered to be unnatural. Using the Q method (McKeown & Thomas 1988), they identified two groups of people. The first group (Factor 1) considered that ‘natural’ meant an absence of human construction and artefacts. For this group the most unnatural landscapes were those with buildings, while the naturalness of treeless pasture was assessed as neutral. The second group (Factor 2) was prepared to accept some ‘appropriate development’ in more natural settings if it was sympathetic to the environment. Large-scale commercial plantation forestry was considered least natural, because of its potential impacts. Treeless pasture was also considered relatively unnatural.

Several authors have found that human perceptions of naturalness are not necessarily in agreement with ecological measures (Lamb & Purcell 1990; Wagner & Gobster 2007). In comparing human judgements of naturalness with measured ecological parameters of naturalness, the former found:

- Vegetation dominated by trees of more than 30 m in height was judged most natural, regardless of 'foliage cover'
- Vegetation dominated by shrubs 2–5 m high was judged to be of lowest naturalness and this judgement was unaffected by vegetation density
- Participants were generally unable to distinguish between levels of disturbance in this vegetation
- As foliage cover increased, participants were increasingly able to distinguish between levels of structural alteration
- As vegetation height increased it became harder for participants to distinguish between natural and altered vegetation. Extensively altered structure in the tallest forest was judged as relatively natural

Gobster et al. (2007) observed that the aesthetic experiences usually associated with wild North American landscapes, encountered in outdoor recreation, emphasise natural scenic beauty (the 'scenic aesthetic'). Landscape perception studies in this context have generally shown a strong positive correlation between perceived scenic beauty and perceived naturalness. For many wildlands, perceived naturalness closely matched more objective indicators of ecological quality. Several exceptions were noted, including ecologically valuable landscapes that are not scenically attractive. In contrast, they found that perceptions of North American agricultural landscapes were typified by an aesthetic of care where active stewardship by people is considered to be in harmony with nature, even though ecological outcomes are not necessarily consistent with that perception. Here there is a greater mismatch between perception and reality for environmental outcomes.

Using the Cape York Peninsula in Far North Queensland as a case study, Strang (1997) described human–environment relationships and why they differed between cultures and sexes. One picture in a photograph elicitation exercise involving the pastoralists was of a pernicious weed, the rubber vine. Very few of the pastoralist women (who largely worked and spent time around the homestead) recognised the vine, and described it as an attractive flower. In contrast, the men who worked out on the station recognised what it was, considered it a noxious weed, and wanted it removed.

Most authors have focused on the visual perceptions of naturalness as sight is a dominant human sense. There are of course other senses – auditory, kinaesthetic and olfactory – that are also relevant in the on-site perception of naturalness.

3.6.2 Naturalness as a component of landscape visual quality

Landscape visual quality can be assessed by specialists (expert approach) or by selected populations of the community (psychophysical approach). Lothian (1999) evaluated the relative merits of each approach, concluding that, because beauty or visual quality is in the eye of the beholder, the psychophysical approach is most robust. In this paper perspectives from both approaches are considered.

Tveit et al. (2006) identified naturalness as one of nine key components in their expert framework for analysing landscape quality. Naturalness has been addressed in a number of landscape assessments (e.g. Wallace 1974; Byrne 1979; Carls 1979; Nieman 1980; Balling & Falk 1982; Mosley 1989; Fairweather & Swaffield 1999) and has often been reported to enhance landscape preference (Ulrich 1986; Kaplan & Kaplan 1989; Purcell & Lamb 1998; Hagerhall et al. 2004). Purcell and Lamb (1984) identified naturalness and the presence of water as two of the four attributes relevant to landscape preference.

There can be a degree of mismatch between the human visual quality preferences for naturalness (Hagerhall et al. 2004) and those for stewardship (Nassauer 1995). Nassauer (1995) observed that people see ecological quality or nature through cultural lenses, and in North America the concept of 'picturesque nature' leads many to prefer landscapes that look cared for, rather than truly ‘natural’. Hagerhall et al. (2004) found that the fractal geometry (fractured shapes with repeating patterns when viewed at increasingly fine scales) found in much of nature could provide an explanation for the well-documented connection between visual landscape preference and naturalness.

The relationship between naturalness and preference is not necessarily linear (Tveit et al. 2006) and the degree of actual naturalness may be less important than perceived naturalness when determining landscape preference (Purcell & Lamb 1998). Familiarity can affect preference, although it is not necessarily the familiar environment that is preferred (Kaplan & Kaplan 1989). Where there is a greater knowledge and concern for indigenous species this has been shown to increase the preference for intact indigenous landscape (Kaplan & Herbert 1987).

Cross-cultural comparisons of preferences for natural environments indicate a relatively high level of agreement on likes and dislikes when cultures are similar (Kaplan & Kaplan 1989). There appear to be preference differences between ethnic groups (Anderson 1978; Kaplan & Talbot 1988) with signs of human influence, neatness and openness being far more important to some ethnic groups than others (Kaplan & Kaplan 1989). Age can also affect natural landscape preferences (Balling & Falk 1982; Miller 1984).

3.6.3 Naturalness as part of some human recreational experiences

Naturalness may influence a recreational experience through its contribution to the recreation setting. The recreational opportunity spectrum (Clark & Stankey 1979) is based on the assumption that the more variation in the environment, the more the variation in the types of recreational experiences a typical user could enjoy (Kliskey 1998). While the spectrum implies a continuum of experience within a continuum of settings, the relationship is not linear (Virden & Knopf 1989).

There are differences in how people relate to nature. In a study where participants were asked to rank photographs of settings based on their naturalness in the important tourist locations of Kaikoura and Rotorua, New Zealand, Newton et al. (2002) found two basic patterns of response. One they called the 'pure nature' view. This view of nature emphasises its wild or natural character without humans. The other view is what they called the 'cultured nature' viewpoint, which sees nature primarily as a resource for human enjoyment and activity. This perspective is defined more in terms of personal experience of the natural environment than by the attributes of the environment itself (Fairweather & Swaffield 2003).

The relationship between setting and the perception of wilderness was examined for the wilderness end of the recreational opportunity spectrum by Kliskey (1998), based on four properties of wilderness perception identified by Kliskey and Kearsley (1993). These properties were the absence of human impacts (artifactualism), aspects of vegetation and forest (naturalness), isolation, and remoteness. The study distinguished four levels of user-perceived wilderness that provided the experience of wilderness to the respective users. Naturalness based on vegetation was part of the wilderness experience, but was not distinguished from the impact of other factors.

Holmes (1995) observed that as wild nature is somewhere people go to contemplate and undertake leisure activities, rather than to do work-related activity, there is a tendency to consider human relationships to nature as being recreational. Several authors (e.g. Landres et al. 1998; Sloan 2002; Ridder 2007a, b) have discussed the distinction between 'natural' and 'wild', concluding that many areas that have high wilderness values also have high naturalness values. This can result in people incorrectly considering the two terms as synonymous. Duelli et al. (2007) has gone so far as to suggest that wilderness is always linked to naturalness (allowing natural processes) and unmanaged nature (no visible human interference).

The definition of natural character proposed in this paper does not include human perceptions and experiences as a part of the core definition. It does, however, include the primary environmental components that determine human perceptions and experiences of naturalness.

3.7 Conclusion

The following definition of natural character is the outcome of evaluations of a suite of naturalness interpretations derived from literature and assessed using a specially constructed set of criteria, appropriate reference conditions and baselines, and the complexities of human perception.

Natural character occurs along a continuum. The natural character of a 'site' at any scale is the degree to which it:

- *is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous 'biological artefacts'*
- *exhibits fidelity to the geomorphology, hydrology, and biological structure, composition, and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable with reference conditions*

Human perceptions and experiences of a 'site's' natural character are a product of the 'site's' biophysical attributes, each individual's sensory acuity, and a wide variety of personal and cultural filters.

This definition has been compared with New Zealand Court interpretations and commentaries on natural character, particularly Court decisions on cases appealed under the Resource Management Act 1991 (Chapter 4). It is being used to develop a methodology to measure natural character and its change in the context of the long-standing New Zealand statutory policy goal to preserve the natural character of the coastal environment and various freshwater environments and their margins. The development and use of methodology will facilitate evaluations of the effectiveness of a variety of measures intended to preserve the natural character of the coastal environment.

3.8 Postscript

The New Zealand Coastal Policy Statement 2010 (Minister of Conservation 2010) was gazetted after the publication of above the paper in the *New Zealand Journal of Ecology*. It is proposed that two additional explanatory cultural context statements accompany the definition of natural character and its single explanatory statement. These explanatory statements address matters potentially arising from the New Zealand Coastal Policy Statement 2010. These statements do not change the definition of natural character: The full definition and its explanatory statements would be as follows:

"Natural character occurs along a continuum. The natural character of a "site" at any scale is the degree to which it:

- *is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous "biological artefacts"*
- *exhibits fidelity to the geomorphology, hydrology and biological structure, composition and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable with reference conditions*

Explanatory cultural context statements:

1. *Human perceptions and experiences of a "site's" natural character are a product of the "site's" biophysical attributes, each individual's sensory acuity and a wide variety of personal and cultural filters*.
2. *Potential opportunities for visual, auditory, kinaesthetic and olfactory experiences of nature can be provided for by preserving (and restoring) the natural biophysical attributes that constitute a site's natural character*."
3. *Recognising and preserving natural character in a way that accounts for regional and other contextual variations in the remaining levels of natural character in different locations and environment types can best be addressed by choosing different levels of natural character as the appropriate thresholds for triggering the policy and management changes that are determined by the classifications of high and outstanding natural character under the 2010 NZCPS."*

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4 Comparison between New Zealand Resource Management Act case law and a “first-principles” definition of natural character

Foreword

This chapter has been prepared as a stand-alone paper. A modified form of this chapter (without the section on defining the coastal environment) has been submitted to a journal for peer review. There is some repetition with respect to the Introduction (Chapter 1) in that this paper summarises the Resource Management Act planning regime for the coastal environment.

Abstract

New Zealand’s natural character policy goal was first incorporated into New Zealand legislation in 1973 as one of the matters of national importance in the former Town and Country Planning Act 1953. This goal has been retained through legislative amendment and today is one of the matters of national importance in the Resource Management Act 1991. The natural character policy goal was also incorporated into protected areas legislation as one of the purposes in the Reserves Act 1977.

Initially there was an active Government programme (including survey, designations in planning schemes and reserve acquisition) to implement this policy goal. Since the late 1980’s implementation has primarily been through the development control legislation- specifically the Resource Management Act 1991. This paper analyses Resource Management Act court decisions that address natural character. This analysis is compared with the recent comprehensive definition of natural character developed for the New Zealand context.

4.1 Introduction

New Zealand has a statutory policy goal of preserving the natural character of the coastal environment and various freshwater environments and their margins. This was developed in response to widespread public concern in the late 1960s and early 1970s about the rapid rate of coastal and lake margin development (Minister of Works and Development 1974). In the 1970’s and early 1980’s a number of mechanisms were deployed to implement this policy including legislative amendments, interagency co-ordination, coastal surveys, use of statutory planning tools and financial mechanisms. Maplesden and Boffa Miskell (2000) and Peart (2009) describe the processes leading to the development of the natural character policy and its incorporation into legislation.

Following changing Government priorities in the late 1980's and early 1990's recent policy implementation has primarily been through the Resource Management Act. Following a landmark 1989 decision by the New Zealand Court of Appeal an extensive body of case law has developed about natural character and the implementation of the relevant sections of the Act.

This paper tracks the change in the emphasis in the implementation of the natural character policy goal and analyses Resource Management Act case law about natural character and the implementation of the relevant legislation. This analysis of case law is compared with the comprehensive definition of natural character developed for the New Zealand context by Froude et al. (2010).

4.2 Natural character policy development

4.2.1 Incorporation into planning and resource management legislation

The natural character policy goal was first incorporated into legislation by a 1973 amendment adding a new section 2B (specified matters of national importance) to the Town and Country Planning Act 1953. The 1953 Act was replaced by the Town and Country Planning Act 1977. This new Act also specified that the "*preservation of the natural character of the coastal environment and the margins of lakes and rivers*…" was a matter of national importance (section 3(1)). The 1977 Act established the framework for maritime planning. Under section 96(1) of the Act, maritime planning areas could include any area of New Zealand between mean high water and the outer limits of the territorial sea, although there was provision (s96(3)) to amend the inner boundary to be above or below mean high water. Matters to be addressed in maritime schemes included "the preservation or conservation of flora and fauna and their habitats, and stretches of coastline of scientific, fisheries, or wildlife importance, historic interest or visual appeal" (Third schedule, item 2).

Following the election of a new government in 1984 there was a period of extensive restructuring of central and local government organisations and reform of the economy. This period, which spanned two governments, also included an extensive review of a large number of resource management statutes affecting land, air and water culminating in the Resource Management Act 1991.

The purpose of the Resource Management Act is to promote the sustainable management of natural and physical resources. As part of achieving this purpose there are five matters of national importance with the first being: "*The preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development"* (section 6(a)). The coastal marine area is defined (in section 2 of the Act) to extend from the 12 nautical mile outer limit of the territorial sea to mean high water springs, with a special mechanism for defining the inland boundary at river mouths. Two other relevant matters of national importance are: the protection of "*outstanding natural features and landscapes*" (section 6(b) and "*areas of significant indigenous vegetation and significant habitats of indigenous fauna*" (section 6(c). These matters have a threshold "qualifier"-"outstanding" and "significant" respectively. This is in contrast to the absence of such a qualifier for natural character in section 6(a).

Under the Resource Management Act there is a hierarchy of decision making instruments. In the coastal environment the hierarchy begins with the mandatory New Zealand Coastal Policy Statement (Minister of Conservation 2010), followed by regional policy statements and then plans by regional and district councils. Regional coastal plans are mandatory and are approved by the Minister of Conservation. These plans provide the decision–making regime for the coastal marine area, although they may include policies and other provisions for the wider coastal environment. A useful summary of the Resource Management Act planning and decision-making regime for the New Zealand coastal environment can be found in Rosier (2005). There is no requirement for a national policy statement or special management regime for any freshwater environments unless they also happen to be within the coastal environment.

4.2.2 Incorporation into the protected areas legislation

One of the three purposes of the Reserves Act 1977 is "*ensuring as far as possible, the preservation of access for the public to and along the sea coast, its bays and inlets and offshore islands, lakeshores, and riverbanks, and fostering and promoting the preservation of the natural character of the coastal environment and of margins of lakes and rivers and the protection of them from unnecessary subdivision and development*." section 3(1)(c). To assist with the implementation of the natural character policy, section 4(2) of the Act requires that the "*…survey of the sea coast, its bays and islets and offshore islands [and] of lakeshores and riverbanks* " be completed and from time to time kept under review.

One of the two other purposes of the Act is "*ensuring as far as possible, the survival of all indigenous species of flora and fauna, both rare and commonplace, in their natural communities and habitats, and the preservation of representative samples of all classes of natural ecosystems and landscapes which in aggregate gave New Zealand its own recognisable character*" (section 3(1)(b)). This purpose underpinned the Protected Natural Areas Programme and much of the subsequent Government action on biodiversity protection for areas that were not under legal protection. It marked a shift from the scenery protection focus of earlier reserves legislation to an increasing emphasis on ecological conservation. The Reserves Act 1977 has not been superseded and the original wording of the natural character purpose remains.

4.2.3 Early mechanisms used to preserve natural character

In the 1970's there was an active programme to preserve coastal, and lake and river margin natural character by the identification of areas of value (through systematic survey) and the protection of these areas (by way of acquisition).

These survey and purchase actions were linked to the local authority planning and development control processes. The annual reports to Parliament prepared by the then Ministry of Works and Development (central government planning agency) and the Department of Lands and Survey (managed national parks and reserves) described the progress of the multi-agency committee and working group which guided reserve surveys and recommended coastal and lake and river margin reserve acquisitions.

The then Department of Lands and Survey surveyed coastal land to identify priorities for protection. This incremental programme progressively surveyed coastal counties over a number of years. Each completed county report was presented to the local council for them to incorporate the findings into their district schemes (prepared under the Town and Country Planning Act 1977), primarily by designations of proposed reserves (Department of Lands and Survey 1974, 1977). Designated coastal areas were progressively acquired although the available funding was never enough.

In the 1980's the focus of the government's environmental survey programmes on unprotected lands changed. The Protected Natural Areas Programme was established to assist the Government to meet its requirements under section 3(1)(b) of the Reserves Act. New Zealand was divided into 85 ecological regions and 268 ecological districts (Biological Resources Centre 1983) that formed the basis of the new programme of ecological survey. In 1987 the then new Department of Conservation took over the functions and administration of the Reserves Act 1977 as well as a variety of other conservation related legislation. By the late 1980's the use of designations in local authority planning documents to identify future reserves for conservation purposes was no longer a preferred tool of government agencies.

As the use of Reserves Act mechanisms began to decrease as a mechanism for preserving the natural character of the coastal environment, a 1989 landmark Court of Appeal decision (*Environmental Defence Society vs Mangonui County Council* (3 NZLR257; 13 NZTCPA, 69/77)) demonstrated that the planning legislation could have a role in preserving the natural character of the coastal environment. Since then an extensive body of case law has been developed around natural character and its preservation. While some of these decisions were made under the Town and Country Planning Act 1977, most address cases under the Resource Management Act 1991.

4.3 Interpretation of natural character in Resource Management Act court decisions

4.3.1 Context

The Resource Management Act 1991 (and its predecessors the Town and Country Planning Act 1953 and 1977) provides a process for applicants or other parties that formally participate in Council decision making processes under the Act, to appeal the Council decisions to the courts. This process has resulted in an extensive body of court decisions known as case law, some of which can have significant value in amplifying the statute law.

Most of the Resource Management Act case law relating to natural character comes from the lowest court -the Environment Court. The Environment Court (previously the Planning Tribunal) hears cases de novo and is not bound by its previous decisions. While decisions on appeals to the High Court and Court of Appeal (both on matters of law) bind the lower courts, few of these decisions address the essence of what is natural character. Accordingly most of the analysis in this paper relates to Planning Tribunal and Environment Court decisions.

Before the landmark 1989 Court of Appeal decision *Environmental Defence Society vs Mangonui County Council* (3 NZLR257; 13 NZTCPA, 69/77)) the courts paid relatively little attention to the requirement to preserve the natural character of the coastal environment. Maplesden and Boffa Miskell (2000) summarised early court decisions addressing natural character. Since the mid-1990s there has been a substantial increase in the number of decisions addressing natural character and in the size and complexity of those decisions. While the early decisions focused on visual matters, ecological matters became increasing important from the early 1990's (Maplesden & Boffa Miskell 2000). This matched the increased biodiversity/ecological emphasis in the implementation of the protected area legislation.

4.3.2 New Zealand Coastal Policy Statement and definitions of natural character

Neither the original (Minister of Conservation 1994) nor the operative (Minister of Conservation 2010) New Zealand Coastal Policy Statement (NZCPS) defines natural character. These statements do, however, identify components that are part of or contribute to the natural character of the coastal environment. In contrast to the original 1994 NZCPS, the 2010 NZCPS states that natural character is not the same as natural features, natural landscapes and amenity values. Policy 13(2) in the 2010 NZCPS states that natural character

"*...may include matters as*:

- *a) natural elements, processes and patterns;*
- *b) biophysical, ecological, geological and geomorphological aspects;*
- *c) natural landforms such as headlands, peninsulas, cliffs, dunes, wetlands, reefs, freshwater springs and surf breaks;*
- *d) the natural movement of air, water and sediment;*
- *e) the natural darkness of the night sky;*
- *f) places or areas that are wild or scenic*
- *g) a range of natural character from pristine to modified;*
- *h) experiential attributes, including the sounds and smell of the sea; and their context or setting*

This does not constitute a definition. Policy 14 actively promotes the restoration or rehabilitation of the natural character of the coastal environment, and provides specific direction for doing this.

Most court decisions analysed for this paper were made following the gazettal of the original 1994 NZCPS, although some decisions preceeded this. None of the decisions analysed or available were made in the context of the 2010 NZCPS.

4.3.3 Methodology used

RMAnet is an online database of New Zealand Resource Management Act court decisions. A search of this database in late 2007 identified about 500 potentially relevant cases. These were listed in order of relevance for natural character as perceived by the database's search engine. Not all cases identified were relevant.

In particular those decisions confirming plan provisions arrived at via negotiation were not able to be used in this research as there was little or no relevant analysis relating to natural character in the court's decision.

Each case from the RMAnet list was assessed beginning with the first case until 100 suitable cases were assessed. Data about each case was recorded in an Excel spreadsheet. This included: the case name; the court that made the decision; the Judge; decision date; whether the decision was officially reported; whether the decision addressed Resource Management Act policy or plan provisions or a resource consent application; the status of the activities in a plan for those situations where the decision addressed a resource consent; location of the application; whether the decision addressed coastal environment and/or freshwater environments; whether the application was for terrestrial or aquatic environments; the environments where natural character was addressed in the court's decision; the proposal; a summary of the court's decision; the effect of the court's decision on the original council decision; the court's intention for natural character; any mitigation required; whether the court defined the coastal environment or natural character; aspects of natural character addressed by the court. Important quotes and concepts relating to natural character and the implementation of section 6(a) of the Resource Management Act were recorded separately. Later, several more recent and relevant cases were added to the evaluation, with several previously assessed cases being removed. These latter cases were where natural character was a relatively minor matter in the Court's decision.

The court's intention for natural character outcomes for each of the 100 decisions was assigned to one of 12 categories. Those categories and the percentage of decisions in each category are described in the results and analysis section.

4.3.4 Results and analysis

Most of the usable cases addressed appeals to the Environment Court or Planning Tribunal. The Court provided a detailed discussion and/or definition of its interpretation of natural character in only about 15% of cases reviewed. Appendix 3 summarises the Court decisions assessed. Where the Court decision discussed on-site impacts on natural character, over and above discussion on the law and previous cases, 48% of those cases (30) discussed the visual component of natural character, 34% of those cases (21) discussed the ecological component of natural character and 18% (11) discussed physical process component of natural character.

The activity spread of the 100 cases reviewed was as follows: rural lifestyle subdivision (17%); residential subdivision (12%); buildings and structures including wind turbines (22%); quarries and mining (3%); other terrestrial (3%); aquaculture (27%); marinas and ports (7%); jetties and wharves (5%); other aquatic (3%). Fifteen percent of cases addressed plan provisions, primarily appeals on a proposed plan or on a plan change or variation. Two cases addressed requirements by designating authorities. Some of the plan changes or variations addressed a particular proposal such as rezoning to permit a subdivision. These cases were included in the activity category totals.

Eighty nine percent of cases addressed the coastal environment. The remainder addressed natural character in relation to freshwater systems or their margins. A few cases addressed the coastal environment as well as some elements of freshwater systems and/or their margins. Sixty five percent of proposals affected terrestrial habitats; 44% affected aquatic habitats and 39% affected the water surface.

Natural character has been addressed in many court decisions. There can be some overlap between s6(a) which addresses natural character and s6(b) which addresses natural features and landscapes. Reasons for this include the dominant role of landscape architects in giving expert evidence on these matters, the two concepts not being entirely independent, and developments sometimes being proposed in areas which are identified in district plans as outstanding landscapes or natural features.

Natural character is recognized in Court decisions as being natural elements, patterns and processes. It is of nature, not culture. Terrestrial natural character is present in a continuum ranging from pristine indigenous vegetation through to indigenous regeneration through to an indigenous and introduced species mix through to introduced species dominant production landscapes through to the built urban environment. It is not necessarily this linear. Introduced species are recognised by the courts as having some natural character values depending on context, although not as much as indigenous species. In the marine environment Court decisions on natural character include marine biota (including marine mammals and seabirds).

The preservation of natural character of the coastal environment, wetlands, rivers, lakes and their margins and the protection of them from inappropriate subdivision use and development is a matter of national importance which Court decisions have determined, is addressed as part of achieving the purpose of the Act in s5 (sustainable management).

In many decisions the Court was focused on the visual aspect of natural character. This generally reflects the nature of the evidence and legal submissions put before it. Where the Department of Conservation has developed a comprehensive framework for addressing natural character (e.g. McRae et al. (2004)), and this is addressed by the witnesses, this can lead to the courts taking a more comprehensive approach to natural character (e.g. Marlborough Sounds). This comprehensive approach is most likely to occur where ecological witnesses frame their evidence to incorporate natural character as a key concept.

Court decisions addressing natural character can refer to the treatment of natural character in similar cases, thereby providing some degree of continuity in decision making. Examples include cross referencing between various Tasman Bay/Marlborough Sounds and Banks Peninsula marine farming cases. Another example is rural- residential subdivision in the former Rodney District.

Natural character preservation is often an important part of the Court decision-making process for appeals on aquaculture, and rural-residential and residential subdivisions. The latter is most likely in situations where subdivision has a non-complying status in the relevant district plan.

Many of the Court decisions relating to natural character in the South Island address marine farming proposals in the coastal marine area. As such these proposals come within the scope of regional coastal plans where the Minister of Conservation has a final approval role for the plan. The seabed involved, is almost always in some form of public ownership and administration. Evidence and the Court decision typically addressed the ecological (as well as the visual) components of natural character.

Many of the Court decisions relating to the natural character in the North Island address coastal subdivisions on private land. While these subdivisions lie within the ambit of the NZCPS, there have typically been no special planning restrictions. Much of the natural character evidence and court discussion have related to the visual component of natural character. Some decisions have included considerable discussion on impact mitigation through the planting of indigenous species. The Court decisions addressed only a small proportion of terrestrial coastal developments. In part this was because relatively few such developments required council consent under the Resource Management Act as a result of them not conforming to the relevant district plan provisions. Of those requiring consent a relatively small percentage were publicly notified thereby providing limited opportunities for parties (other than the council or developer) to make submissions to the council and later appeal to the Courts. This means that a considerable amount of terrestrial coastal development has occurred outside of a detailed assessment of its impact on natural character.

Sometimes revegetation/ecological restoration mitigation has been used to offset the natural character impacts of the relatively limited building associated with some rural-residential subdivisions. An example was 10ha of planting per lot in the Arrigato case in Rodney District (*Arrigato v Auckland Regional Council (A115/99); Arrigato v Auckland Regional Council (CA84/01) [2000] NZRMA 481; Arrigato v Auckland Regional Council A145/2002*). Depending on the plan provisions, the Courts may not approve lower levels of planting because of the precedent effect. In. *Murphy v Rodney District Council (A133/2003)* 2ha of planting per lot was declined. Whether the Court accepts the offered mitigation also depends on the impact of the actual development and the perceived benefits of the mitigation. In *Matakitaki Trust v Queenstown Lakes District Council* (W10/2006) the development impacts were judged as major and the ecological restoration programme benefits were ambiguous and so the Court declined the application.

The context of a proposal is critical. This includes the location (relative to existing development and areas of high natural character, as well as the scale of the proposed development. A proposal for a development that has a discretionary status in the relevant planning document may be declined even if the activity is generally suitable in the environment/zone (e.g. *Marlborough Seafoods v Marlborough District Council (W12 98) [1998] NZRMA21*).

Even the long standing residential zoning for an area may not prevail if the consents required for associated activities will have a major impact on natural character (e.g. *Kotuku Parks v Kapiti Coast District Council* (A73/2000)). Nearby development may increase the relative natural character of what remains, depending on its qualities (e.g. *Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council* (W25/2002)). Alternatively it can be seen as consolidating development as in policy 6(1)(c) of the 2010 NZCPS.

There seems to be a lesser emphasis on the natural/ecological pattern and processes of natural character, as opposed to the visual perception elements, in the decisions of the Auckland Division of the Environment Court. This may reflect less Department of Conservation input, the lack of ecological evidence being included within a natural character framework, less reference to the decisions of the Wellington and Christchurch Divisions of the Court, or because the parties have focussed on visual issues.

Table 4.1 summarises the natural character concepts identified in the 100 assessed decisions. While common themes are repeated in a number of decisions, there are some matters where the treatment by the courts has been inconsistent. One of these matters is the impact of introduced trees (typically conifers) on natural character. In part this is likely to be due to the different contexts in which decisions are being made. In *Kapiti Environmental Action v The Kapiti Coast*

District Council (A60/02) the Court acknowledged that while pine plantations were ugly at harvest time and may have replaced some native species, for much of the cycle pine forest was relatively pleasant to view compared to dwellings amongst the sand dunes. In contrast in *Rohaotia Marine Farms v Marlborough District Council (W5/106)* the Court found that cleared pine plantations can have an industrial look and the replacement plantations may not offer much naturalness. In another context the Court found that planted trees with limited structures can result in higher natural character compared to a completely pastoral landscape (*Save the Bay v Christchurch City Council (C50/02*)). Lastly, in an area of significant indigenous regeneration the Court held that wilding (introduced) pines modified natural character only slightly (*Kuku Mara Partnership v Marlborough District Council (W39/2004)*).

Table 4.1: New Zealand court interpretations of natural character: This was developed from an analysis of 100 court decisions on appeals made under the Resource Management Act

Natural character concept	**Decision example(s)**
Natural character is derived from nature	Aqua King (Anokoha Bay) v Marlborough District Council (W71/97) Kuku Mara Partnership (Admiralty Bay)v Marlborough District Council (W037/2005)
The degree of natural character depends on the extent to which natural elements, patterns and processes occur	Pigeon Bay Aquaculture v Canterbury Regional Council C179/03 Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004) The Matukituki Trust v Queenstown Lakes District Council (W10/2006)
Natural character includes ecosystems and ecological processes	Gill v Rotorua District Council (W29/93)
Natural character elements include: terrestrial landforms and coastal features, terrestrial vegetation, birdlife and feeding grounds, intertidal areas, estuaries, marine vegetation, seabirds, marine mammals, clear water quality, coastal ecosystems, seascapes, offshore waters	Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004) Golden Bay Marine Farmers v Tasman District Council (W42/2001) Trio Holdings v Marlborough District Council (W103/96)
Natural character processes include natural tidal movements, natural sedimentation, natural lake levels, animal migrations/movements	Golden Bay Marine Farmers v Tasman District Council (W42/2001) The Matukituki Trust v Queenstown Lakes District Council (W10/2006)
Natural succession and regeneration processes are part of natural character	Gill v Rotorua District Council W29/93 Kuku Mara Partnership v Marlborough

Natural character concept	Decision example(s)
	District Council (W39/04)
Natural character excludes built elements such as buildings, structures and infrastructure	Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004) Kuku Mara Partnership (Admiralty Bay)v Marlborough District Council (W037/2005)
Natural character has a relative rather than an absolute value	Doves Bay Society Inc v Far North District Council (C126/02)
The highest natural character is where there has been least modification/ where environments are composed entirely of natural elements, particularly indigenous communities	Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004) Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council (W25/2002)
Natural character is present in a continuum. This continuum ranges from urban to wilderness	Doves Bay Society Inc v Far North District Council (C126/02) Kuku Mara Partnership (Admiralty Bay) v Marlborough District Council (W037/2005)
Even highly modified coastal environments can have some natural character	Doves Bay Society Inc v Far North District Council (C126/02) Pigeon Bay Aquaculture v Canterbury Regional Council C179/03
An area does not have to be pristine for natural elements, patterns and processes to dominate	King-Turner v Marlborough District Council (W81/2000)
Natural does not mean pristine or endemic to New Zealand	Eyres Eco_Park v Rodney District Council (A147/2004) Harrison v Tasman District Council ()
Visual qualities are part of natural character	Horn v Marlborough District Council (W30/05) Trio Holdings v Marlborough District Council (W103/96)
Experiential recognition of what is natural character relates to natural elements and patterns and an absence of built elements and unnatural patterns. It does not include subjective aesthetic assessments based on taste. In natural character terms the presence of unnatural patterns are independent of viewers experiencing them.	Browning v Marlborough District Council (W20/97) Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council (W25/2002 Pigeon Bay Aquaculture v Canterbury Regional Council C32/99 (para 58, p32)
Natural character differs from beauty	First Wave v Marlborough District Council W46/97
Natural character differs from wilderness	Gannet Beach Adventures Ltd v Hastings District Council W90/04)
People's perception of naturalness can differ significantly from reality. "Natural character is derived from a large	Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council (W39/04) (para 393, p110)

Natural character concept	Decision example(s)
number of characteristics that have nothing to do with people's perception of them"	
People vary in their interpretations of naturalness	Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004)

Table 4.2 summarises New Zealand courts' interpretations on the implementation of section 6(a) of the Resource Management Act. This excludes interpretations of what constitutes natural character as these have been addressed in Table 4.1.

Table 4.2: New Zealand court interpretations on the implementation of section 6(a) of the Resource Management Act: This was developed from an analysis of 100 Resource Management Act court decisions

Policy concept	Decision example(s)
The preservation of natural character is subordinate to the purpose of the Act which is the promotion of sustainable management	New Zealand Rail v Marlborough District Council AP169/93
The preservation of the natural character of the coastal environment (and other listed systems) is a matter of national importance	DG of Conservation v Marlborough District Council W89/97
The natural character of an area need not exhibit any special attributes or be of national importance to warrant protection	Arrigato v Auckland Regional Council A115/99; Clyma v Otago Regional Council W64/94
Modification is not a reason to ignore the requirement to protect coastal natural character. Developments in the vicinity may increase the importance of protecting the remaining natural character in a particular location	New Zealand Shipping Federation v Marlborough District Council W38/2006 DG of Conservation v Marlborough District Council W89/97
Context is essential when assessing the appropriateness of a modification to natural character. While a use may generally be appropriate in an environment (e.g. coastal marine area) or zone it is not necessarily appropriate in all locations in that environment or zone	DG Conservation v Marlborough District Council W89/97 Lowe v Auckland Regional Council (A21/94) Pigeon Bay Aquaculture v Canterbury Regional Council C32/99 Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004)
Inappropriateness in the context of impacts on natural character is to be decided on a case by case basis depending on the circumstances of a particular case	New Zealand Rail v Marlborough District Council (AP169/93)
In assessing a development proposal, the	Pigeon Bay Aquaculture v

Policy concept	Decision example(s)
focus of assessment is not the absolute level of natural character but whether that proposal will adversely affect natural character and if so to what extent	Canterbury Regional Council (C179/03)
Enhancement of natural character is required as well as protection in many locations	Murphy v Rodney District Council (A133/2003)
Mitigation should be appropriate to the particular environmental circumstances and the damaging impacts of the proposed development	Stapylton-Smith v Banks Peninsula District Council (C191/04)

The Resource Management Act does not apply to controls on the harvest or enhancement of populations of aquatic organisms that are fisheries resources controlled under the Fisheries Act 1996 (*Challenger Scallop Enhancement Company v Marlborough District Council [1998] NZRMA 342*). This limits the comprehensiveness of Resource Management Act's treatment of natural character in aquatic ecosystems.

4.3.5 Court's intention for natural character outcomes

Table 4.3 summarises the analysis of the courts' intentions for natural character outcomes for 100 Resource Management Act cases (as in Appendix 3). In 34% of cases the court largely approved the proposed development; in 14% of cases the court approved a reduced development and/or one with substantial mitigation, and in 42% of cases the court declined the proposal.

Table 4.3: Analysis of the Courts' primary intention for natural character outcomes: This was developed from the analysis of 100 decisions made by the Courts under the Resource Management Act

Decision	Category	Percentage of cases	Description of intent for natural character
Development or proposal declined	A	30	The only way to address adverse effects on natural character is for there to be no development of the nature proposed
	B	5	While the site's natural character values have been degraded (at least in part) this is not an excuse for further development and/or the site will improve with natural succession processes
	C	2	Natural character is not a major factor in the decision to decline
	D	5	The development was declined primarily because of the precedent effect and/or the proposal was contrary to s6 and/or New Zealand Coastal Policy Statement and/or the relevant zone provisions in the plan
Development largely approved	E1	15	Development assessed to have minor adverse effects on natural character
	E2	5	Benefits of the proposal are so important (nationally) that the development should proceed even if there will be adverse effects on natural character
	E3	14	The site has been compromised by earlier development and/or consents issued
Development approved with significant mitigation	F1	5	Mitigation of potential adverse effects addressed through one or more of a significant reduction in scale, a reduction in the term of consent, or a substantial change in style
	F2	5	Mitigation of potential adverse effects addressed through substantial compensatory offset works
	F3	4	Both of F1 and F2
Changes to plan provisions directly affecting natural character where categories A-F not used	G	8	Upheld or tightened measures to improve natural character protection
	H	0	The modification of the plan provisions decreased their effectiveness for protecting natural character outcomes but were required to address concerns raised by others

4.4 Defining the coastal environment

Neither the Resource Management Act, nor its predecessors, nor the 1994 New Zealand Coastal Policy Statement (Minister of Conservation 1994) define what constitutes the coastal environment. The coastal marine area is part of the coastal environment and this is defined in the Resource Management Act. The ambiguity relates to what constitutes the landward boundary of the coastal environment. Relatively few court decisions have discussed the location of the inland boundaries of the coastal environment.

In *Crooks and Sons Ltd v Invercargill City Council and Southland Regional Council (C8/97*) the Environment Court said "*Cases under [The Town and Country Planning Act]… held that the coastal environment is an environment in which the coast is a significant part or element. What constitutes the coastal environment will vary from place to place and according to the position from which it is viewed. Where there are hills behind the coast it will generally extend up to the dominant ridge behind the coast – see for example Northland Regional Planning Authority v Whangarei County Council (1977) DA 4828…Counsel did not refer to any cases under the present Act that specifically deal with this issue and we have been unable to find any ourselves. Most of the cases considered under the present Act have been cases where the issue has been whether the coastal environment has a natural character and if so whether the proposed activity will adversely affect it….*(p95-97)

In *S Martin-Webber and S Martin-Webber v Hutt City Council and Jourdan Developments Limited* (W23/03) the Environment Court discussed whether the proposed subdivision in the hills adjoining Kowhai Street, Eastbourne was in the coastal environment. They reported that several counsel referred to a decision *Northland Regional Planning Authority v Whangarei County Council (1977)* (Appeal Board Decisions page A4828-4831) which had held that where there are hills behind the coast, the coastal environment will generally extend up to the dominant ridge behind the coast. In the case in question the Court found that the site "*lying between the dominant ridge and the coast, can be considered as being within the coastal environment for the purpose of the Resource Management Act*" (para 39, p8). The Court also observed that the site did not have a coastal interface and that there was no coastal element in the vicinity of the site.

Policy 1(2) of the 2010 New Zealand Coastal Policy Statement (Minister of Conservation 2010) states that 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; and*
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*
i) *Physical resources and built facilities, including infrastructure, that have modified the coastal environment*

While Policy (10(2) does not actually constitute a definition, it does provides more guidance on the boundary of the coastal environment than had previously been available. As this guidance was not available during the methodology development and testing phases, the following working definition was used for the purposes of methodology development and trialling:

The coastal environment includes the coastal marine area (as defined in s2 of the Resource Management Act) plus the coastally influenced terrestrial and freshwater environments. The terrestrial and freshwater components of the coastal environment include:

- *Areas where existing or former ecosystems are/were part of natural coastal processes (e.g. active and consolidated dunelands including dune swales and lakes, freshwater wetlands hydrologically linked to estuarine wetlands, tidal reaches of rivers)*

- *Areas in the coastal catchments, especially where these catchments can be readily seen from the near shore coastal marine area (e.g. most of the Bay of Islands)*

This definition is consistent with Policy 1(2) in the 2010 NZCPS.

4.5 Comparing natural character definition and court interpretations

Froude et al. (2010) developed the following definition of natural character that specifically addressed the New Zealand environmental, policy and legal context.

"Natural character occurs along a continuum. The natural character of a "site" at any scale is the degree to which it:

- *is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous "biological artefacts"*
- *exhibits fidelity to the geomorphology, hydrology, and biological structure, composition and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable to reference conditions*

Human perceptions and experiences of a "site's" natural character are a product of the "site's" biophysical attributes, individual sensory acuity and a wide variety of personal and cultural filters."

Table 4.4 compares this definition with the interpretations of natural character derived from the analysis of Resource Management Act case law as summarised in Table 4.1. A number of court decisions address how the degree of natural character depends on the extent to which natural elements, patterns and processes occur (e.g. *Pigeon Bay Aquaculture v Canterbury Regional Council C179/03; Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004); The Matukituki Trust v Queenstown Lakes District Council (W10/2006)*).

Table 4.4: Defining natural character: comparison between the definition in Froude et al. (2010) and the analysis of Resource Management Act case law

Components of the natural character definition by Froude et al (2010)	**How this matter is addressed in Resource Management Act case law**
Natural character occurs along a continuum.	This is supported, e.g. Doves Bay Society Inc. v Far North District Council (C126/02); Kuku Mara Partnership (Admiralty Bay) v Marlborough District Council (W037/2005)
It is part of nature, particularly indigenous nature	Natural character is derived from nature e.g. Aqua King (Anokoha Bay) v Marlborough District Council (W71/97) There is an emphasis on indigenous nature because areas of indigenous cover are considered more natural than those that are not, e.g. Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004); Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council (W25/2002)
It is free from the effects of human constructions	This is supported, e.g. Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004)
It is free from the effects of non-indigenous "biological artefacts	Court decisions relating to the naturalness of introduced production systems (e.g. plantation forestry using introduced species) are variable and seem to depend on the context. By focusing on effects, the definition is consistent with the case law.
It exhibits fidelity to the geomorphology, hydrology and biological structure, composition and pattern of the reference conditions chosen	The case law identifies a range of natural character elements including: terrestrial landforms and coastal features, terrestrial vegetation, birdlife and feeding grounds, intertidal areas, estuaries, marine vegetation, seabirds, marine mammals, clear water quality, coastal ecosystems, seascapes, offshore waters; e.g. Gill v Rotorua District Council (W29/93); Freda Pene Reweti Whanau Trust v Auckland Regional Council (A166/2004); Golden Bay Marine Farmers v Tasman District Council (W42/2001); Trio Holdings v Marlborough District Council (W103/96). The degree of natural character present at a site depends on the extent to which natural elements, patterns and processes occur.
It exhibits ecological and physical processes comparable to reference conditions	Natural character processes include natural tidal movements, natural sedimentation, natural lake levels, animal migrations/movements; e.g. Golden Bay Marine Farmers v Tasman District Council (W42/2001); The Matukituki Trust v Queenstown

Components of the natural character definition by Froude et al (2010)	How this matter is addressed in Resource Management Act case law
	Lakes District Council (W10/2006) Natural succession and regeneration processes are part of natural character; e.g. Gill v Rotorua District Council W29/93; Kuku Mara Partnership v Marlborough District Council (W39/04) The degree of natural character present at a site depends on the extent to which natural elements, patterns and processes occur.
Human perceptions and experiences of a "site's" natural character are a product of the "site's" biophysical attributes, individual sensory acuity and a wide variety of personal and cultural filters	The statement is consistent with decisions from the courts. Some decisions observe that there is a difference between perception and reality (e. g. Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council (W39/04). Several decisions comment that people's experience of natural character is based on natural components of the environment; e.g. Browning v Marlborough District Council (W20/97); Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council (W25/2002; Pigeon Bay Aquaculture v Canterbury Regional Council (C32/99).

4.6 Conclusion

The analysis in this paper has demonstrated that the comprehensive definition of natural character developed by Froude et al. (2010) is consistent with the overall tenor of interpretations in decisions from the New Zealand Environment Court/former Planning Tribunal and the higher courts. It is therefore appropriate that this comprehensive definition of natural character form the basis for developing quantitative methodology for measuring natural character and its change in the New Zealand context. The methodology so developed is appropriate to use for planning and environmental assessment in the context of the Resource Management Act in New Zealand.

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Arrigato v Auckland Regional Council (CA84/01) [2000] NZRMA 481

Aqua King (Anokoha Bay) v Marlborough District Council (W71/97)

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Clyma v Otago Regional Council (W64/94)
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Harrison v Tasman District Council (W42/93)
Horn v Marlborough District Council (W30/05
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5 QINCCE: a Quantitative Index for measuring the Natural Character of the Coastal Environment: methodology justification and overview

Foreword

This chapter has been prepared as a stand-alone paper to be submitted to a journal after modifications have been made to address the journal's requirements, including changing cross-referencing to other chapters. There is some repetition with earlier chapters as this chapter includes the context for the methodology.

Abstract

An analysis of environmental monitoring and measurement systems was undertaken to specify criteria and develop a framework for measuring natural character and its change for New Zealand coastal environments. Essential ingredients sought were a quantitative methodology that used indicators to measure key components of natural character as specified in a comprehensive definition of natural character. An assessment of analysis systems used for reporting results identified that the best way to report natural character would be to use a set of indices with scores between 0 and 1.

The QINCCE (Quantitative Index for measuring Natural Character of the Coastal Environment) methodology uses the same basic framework in all categories of terrestrial and aquatic coastal environment. Mapped units which contain relatively homogeneous levels of natural character are depicted manually and subsequently digitised at a scale appropriate to the purpose of the measurement and information available. A set of indicators and associated parameters address the components of a comprehensive definition of natural character. Measurements of the core parameters are used to calculate three sub-indices: ecological naturalness index; hydrological and geomorphological naturalness index; and freedom from buildings and structures index. These three sub-indices are combined to give an overall natural character index for each unit.

Second tier parameters are available for those areas or situations where a more comprehensive measurement of a wider range of parameters is required. The

oblique *Viewpoint* perspective uses the same core parameters, excluding building and structure height, as standard plan-view assessments, and can be used in detailed assessments.

5.1 Introduction

New Zealand has a long-standing statutory policy goal to preserve the natural character of the coastal environment, riparian and various freshwater environments, and to protect those environments from unnecessary/inappropriate subdivision, use and development. This policy was developed in the early 1970s as part of the response by the then government to widespread public concern about the rapid rate of coastal and lake-margin development (Minister of Works and Development 1974). It has been one of the matters of national importance in planning/development control legislation since 1973 (and now section 6(a) of the Resource Management Act 1991), and one of the three purposes of the Reserves Act 1977 (section 3(c)) since 1977.

Peart (2009) describes a number of New Zealand coastal developments that have taken place since 1973. In the 1990s and from 2000-2007, a boom in coastal property development saw many new coastal subdivisions and the construction of many large houses with supporting infrastructure, often in prominent coastal locations (Peart 2009). This intensive development has reduced the natural character of many coastal areas (Peart 2009).

Many houses have been built in low-lying and/or erosion-prone locations and are vulnerable to the effects of future climate change (especially increased storminess and sea-level rise). Jacobson (2004) found that the 1994 New Zealand Coastal Policy Statement had been largely ineffective in preventing development in areas of low-moderate coastal-hazard risk and ineffective in avoiding the continuing use of hard property-protection works that have adverse impacts on coastal natural character. Other major trends affecting terrestrial and freshwater coastal natural character since 1973 include:

- The establishment of a suite of ongoing ecological restoration projects on limited areas of coastal mainland and more typically islands (Peart 2009)

- An increase in the magnitude of infestation by environmental terrestrial and freshwater weed species especially near human settlement (Timmins & Williams 1991; Sullivan et al. 2005)
- The loss of, or major damage to, many remnant coastal pohutukawa (*Metersideros excelsa*) in northern New Zealand due to land clearance, fire and possum damage (Hosking et al. 1989)
- Cumulative effects of local native vegetation removal
- The removal of farming and forestry subsidies in the early 1980s leading to some areas of former coastal farmland beginning the reversion process towards native forest (e.g. parts of Northland)

There have also been many changes to natural character of the marine coastal environment since 1973 including:

- The mostly recent establishment of more than 30 no-take marine reserves covering 7% of New Zealand's territorial sea (although 99% of that is around two isolated groups of offshore islands-the Kermadec and Auckland Islands (http://www.doc.govt.nz/conservation/marine-and-coastal/marine-protected-areas/marine-reserves-a-z/, accessed 2 March 2010))
- Negative cumulative impacts on marine ecosystems resulting from commercial and recreational harvest of fish and other marine biota (Parsons et al. 2009)
- Catchment runoff and other discharges; catchment land uses leading to accelerated sedimentation in many marine environments and adverse effects on marine biota (Schwarz et al. 2006b; Morrison et al. 2009; Swales et al. 2009)
- Port, marina and related infrastructure construction and expansion;
- Causeways and new bridging mainly associated with roading infrastructure (e.g. the partial causeways and abutments associated with the recently constructed state highway bridge across the Ahuriri Estuary at Napier)
- The introduction of canal style housing and associated facilities to New Zealand (e.g. Whitianga on the Coromandel Peninsula)

- The large scale establishment of marine aquaculture in locations such as the Marlborough Sounds, Coromandel and parts of eastern Northland (Rennie 2002); the 1990s boom resulting in a five-fold increase in the demand for aquaculture space (http://www.mfe.govt.nz/issues/aquaculture/ accessed 2 March 2010); and current Government intent to increase the range and amount of marine aquaculture three fold (Minister of Fisheries 2010)

A comprehensive definition of natural character that addresses the New Zealand environmental, legal and policy context has been developed (Froude et al. 2010) as follows:

"Natural character occurs along a continuum. The natural character of a "site" at any scale is the degree to which it:

- *is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous "biological artefacts"*
- *exhibits fidelity to the geomorphology, hydrology and biological structure, composition and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable with reference conditions*

Human perceptions and experiences of a "site's" natural character are a product of the "site's" biophysical attributes, each individual's sensory acuity and a wide variety of personal and cultural filters."

The components of natural character in this definition have not been systematically monitored and so it has not been possible to report on how well the national policy goal of preserving coastal natural character has been addressed. A major reason for the lack of monitoring has been the absence of a suitable methodology for measuring coastal natural character and its change. Such a methodology should: apply to the different types of New Zealand coastal environment; address the different components of natural character; be quantitative so as to facilitate the measurement of change locally and enable the consistent aggregation of results across different types of coastal environment.

The purpose of this paper is to evaluate potential approaches and develop the framework for a quantitative methodology for measuring natural character and its change. The paper begins with an analysis of existing New Zealand approaches to the assessment of natural character. This is followed by an analysis of potential methodological approaches to measuring and reporting coastal natural character and its change. The remainder of the paper describes a new methodology: QINCCE (Quantitative Index for measuring Natural Character of the Coastal Environment). This methodology uses a consistent framework for terrestrial and aquatic coastal environments. While the same parameters are used where possible, fundamental differences between coastal environments are addressed by the use of environment-specific parameters where appropriate. Comparisons of natural character levels for different types of coastal environment are made possible by the use of a set of indices.

5.2 An analysis of existing New Zealand approaches for assessing natural character

Natural character assessments in New Zealand have primarily been associated with the implementation of the Resource Management Act 1991 (and to a lesser extent its predecessor the Town and Country Planning Act 1977). The most common approach has been the descriptive assessment with or without a qualitative natural character rating. This approach has typically been used by applicants and others involved with submitting on or processing resource consent applications affecting the coastal environment, wetlands, rivers and lakes and their margins. Many of the decisions of the Environment Court and former Planning Tribunal that address natural character include summaries of the qualitative evidence on natural character given by expert witnesses.

A variety of approaches have been used in these descriptive assessments. Spatial and temporal coverage has been patchy. Because of these limitations the descriptive approach would not provide a good basis for measuring natural character change. While it would be theoretically possible to establish a consistent national framework for describing natural character, it would be more beneficial to develop a national framework for the quantitative measurement of natural character. Benefits of quantitative national framework include providing a robust system for: measuring natural character change; comparing natural character in different types of coastal environment; and evaluating potential outcomes for natural character under different scenarios. The descriptive approach could be used alongside the quantitative methods in those situations where detailed one-off assessments are required.

Some district councils have undertaken comprehensive landscape assessments in the context of their Resource Management Act responsibilities (e.g. Whangarei District, Queenstown Lakes District). The associated district plan provisions (for land above mean high water springs, plus the surface of inland water bodies) primarily relate to landscape assessments under sections 6(b) and 7(c) of the Resource Management Act (outstanding natural landscapes and features; and amenity values respectively). They are addressed in this paper because, at the district council level, natural character preservation requirements (section 6(a) of the Resource Management Act) are sometimes incorrectly conflated (chapter 4) with landscape matters.

Queenstown Lakes District Plan (Queenstown Lakes District Council 2009) maps include identified "outstanding natural landscapes" and "visual amenity landscapes" while natural character is addressed only as a minor part of the policies relating to landscapes and nature conservation. In Whangarei District "natural character areas" have been identified as part of a lengthy process of mapping landscapes in the context of the Resource Management Act (Paul Waanders, Whangarei District Council, pers.comm.).

The identification of areas deemed to have "outstanding", "significant" or equivalent landscape and/or natural character values within Resource Management Act plans is an iterative process where expert proposals are modified to address political and other constraints. At the district level reports underpinning the identification stage typically have a broad scale landscape focus. Often some important components of natural character (c.f. definition in Froude et al. (2010)) are not addressed. The units are often delineated on a landform/ geomorphological basis and can be relatively heterogeneous from a natural character perspective. The assessment process is typically a mixture of description and simple categorical scoring. The size and homogeneity of the units and the type of assessment system mean that this approach is unlikely to be sufficiently sensitive enough to detect many of the cumulative changes that occur in the coastal environment.

Regional coastal plans address the coastal marine area. Under the Resource Management Act 1991 the coastal marine area is defined to include the territorial sea from mean high water springs out to 12 nautical miles and the marine-influenced lower stretches of rivers. The direction provided by the New Zealand Coastal Policy Statement (Minister of Conservation 1994, 2010) and the Minister of Conservation approval process for coastal plans (s19, schedule 1, Resource Management Act) has meant that these plans are more likely than other Resource Management Act plans to address natural character directly. For example, the Bay of Plenty Regional Coastal Environment Plan (which contains policies and rules for the coastal environment below mean high water springs and only policies for the coastal environment above this boundary) includes a chapter on natural character. Although the chapter provides a comprehensive policy basis for establishing a Coastal Habitat Preservation Zone (Bay of Plenty Regional Council 2005) only limited areas of coastal-margin public reserve land below mean high water springs that is of high ecological value, are included in the operative plan.

A natural character framework for the Marlborough Sounds (McRae et al. 2004) differentiated 11 terrestrial and 8 marine units based on chemical and physical parameters that were considered to be major determinants of indigenous biodiversity in natural systems. The terrestrial unit differentiation was based on rock type, geomorphology, tectonic regime, maritime influence, and rainfall. For the marine environments unit differentiation was based on wave exposure, tidal influence, turbidity, sedimentation, temperature, salinity, nutrient availability and substrate composition. As these parameters have differing influences on indigenous biodiversity in different locations, each unit could be characterised by a unique set of physical, chemical and biological attributes. The parameters used to differentiate units, especially in the terrestrial environment, provide a framework for describing the components that comprise the natural character of an area. However, many of the factors used to define units are not important determinants of present levels of natural character and some important factors are not used. The resulting units are generally very diverse from a natural character perspective. This limits their utility to be the framework in which changes in natural character are measured.

An ecological assessment of natural character (Focus Resource Management Group 2010) for Thames Coromandel District Council (TCDC) specified criteria for, and mapped (in a separate database), the spatial extent of the areas of "high natural character" throughout the district using the following ecosystem categories: sand dunes, gravel and boulder beaches, coastal wetlands, coastal forest and "rivers". The latter included those rivers and their catchments where at least 90% of the catchment had an indigenous vegetation cover. This approach provides a good resource for planning purposes. While changes in extent could be monitored, this approach would be unlikely to provide the type of information needed for consistent monitoring of changes in ecological, hydrological and geomorphological condition or the impact of structures in the identified areas of "high natural character". Changes in natural character would not be addressed for other parts of the coastal environment.

Six "indicators" of terrestrial natural character were identified at a February 2002 Ministry for the Environment workshop: abiotic factors (landform); vegetation type (native to exotic); vegetation cover and patterns; land uses/buildings and structures (presence/absence); seascapes and water areas; and natural processes (Stephen Brown Environments 2008). Following this, the Ministry contracted Boffa Miskell to prepare and trial provisional guidelines for assessing the landscape (versus the ecological) component of natural character for the terrestrial coastal environment. The provisional methodology assessed natural character in coastal landscape areas and units (defined on a landform basis and at a relatively large scale). The following six "criteria" were each scored on a six-point scale (0 to 5) and summed (without weightings) to give a total score out of a maximum score of 30: naturalness of landform; naturalness of "waterform" (rivers, wetlands); amount of indigenous vegetation cover; "naturalness of vegetation pattern" (fragmentation of indigenous vegetation; geometry/linearity of exotic vegetation); absence/presence of buildings; and absence/presence of infrastructure services (Boffa Miskell 2002a,b).

Consistent with the brief provided, this methodology did not address the marine environment and only partly addressed ecological components of natural character. A similar approach (but using slightly different parameters) was tested early in the development of the QINCCE methodology. The approach was rejected because it was not sensitive enough to detect many of the cumulative changes in the coastal environment. One component of the Boffa Miskell methodology that has been retained for the QINCCE methodology is the scoring of a variety of parameters within spatial units. However, the QINCCE methodology uses a different basis for defining units, and scores and combines the parameters differently. In addition, the QINCCE methodology is able to be used at a range of scales and for a wide range of purposes.

In contrast to the Resource Management Act focus of the previous examples, a methodology for measuring "natural character" (the term used to represent the degree to which the pre-human condition of a habitat or ecosystem remains - measured on a scale from 0 to 1) was developed to assist the Department of Conservation measure conservation achievement (Department of Conservation 2001). As part of a trial in the Twizel District, Geographic Information Tools (GIS) tools were used to analyse spatially-based datasets to quantify five broad pressure indicators of loss of natural character (Stephens et al. 2002):

- Plant and animal removal - comparing present biotic cover of a site against what was thought to be there historically
- Animal pest pressure - the level of consumption pressure on native biota as indicated by the level and abundance of introduced animal pests
- Weed pressure - the level of competition pressure on native plants as indicated by the percentage cover of introduced plants
- Resource modification - the intensity of disturbances as indicated by the amount of change to natural hydrology, nutrient, substrate, light and temperatures regimes
- Fragmentation - the change in the surrounding landscape associated with ecosystem fragmentation, loss of connectivity and edge effects

The methodology for measuring conservation achievement (Department of Conservation 2001) is conceptually robust, but its complexity has meant that managers have found it difficult to understand and it has not been adopted (Stephens, pers.comm. 2009). This methodology does not specifically address the impacts of human structures, which is particularly relevant for many coastal environments. The methodology requires a large amount of spatially referenced data and/or a number of assumptions need to be made where the necessary data are unavailable. Some of the concepts have been adapted for use in the new QINCCE methodology (e.g. aggregating parameter data into an index with a scale from 0 to 1).

While the use of GIS tools to manipulate national digital data sets for a range of purposes is becoming increasingly common, the utility of this approach for assessing changes in natural character of the New Zealand terrestrial coastal environment is limited by the range and completeness of the available digital datasets. Brabyn (Brabyn 2005, 2007) used GIS tools to manipulate several national digital datasets to measure components of natural character for New Zealand terrestrial landscapes. Land cover was determined in neighbourhood radii of 500m, 1km and 2km; utility density was calculated in neighbourhood radii of 1km and 2km; and mean and minimum property size were calculated separately for neighbourhood radii of 500m, 1km and 2km (Brabyn 2005). These 11 "representations" were each assigned a score from 1("natural") to 5 ("developed"). Scores were then aggregated using a majority function that gave each cell the most common score.

Brabyn's methodology addresses only some components of terrestrial natural character (c.f. definition in Froude et al. 2010) and is not suitable for aquatic environments. The method's use of neighbourhood radii is likely to lead to higher natural character scores for locations close to the coastline than may be justified and there is likely to be a reduced sensitivity for detecting change. This is because where the land is very close to mean- high- water -springs, the radii would probably encompass a relatively large component of coastal marine area which typically has low levels of utilities and large "property" sizes, and the water "cover" is classified as having a high level of naturalness.

Assessing change in coastal land cover using the LCDB (minimum mapping unit of 1 hectare) means that many of the cumulative small-scale incremental cover changes in the terrestrial coastal environment are unlikely to be detected.

Digitising the boundaries of active dunelands based on topographic maps for the 1950s, 1970s and 1980s and aerial photographs for the 1990s, allowed Hilton et al. (2000) to track changes in the extent of New Zealand's active dunelands since the 1950s. This is a useful resource of historical change in aspects of natural character for dunelands. It may be possible to use GIS tools and historical information (e.g. old maps, oblique and aerial photographs) to evaluate historical changes for other components of coastal natural character.

A fundamentally different approach has been to assess public perception of naturalness. Using the Q methodology (McKeown & Thomas 1988), Fairweather & Swaffield (1999) asked participants to sort or rank a set of Coromandel photographs from most to least natural. These "Q sorts", as they are known, were factor- analysed to identify the "factors" or distinctive value sets expressed. Several councils (e.g. Auckland Regional Council, Whangarei District Council) have sought public preferences for different types of landscapes, rather than perceptions of naturalness (Whangarei District Council 1995).

The definition of natural character in Froude et al. (2010) distinguishes between objective measures and human perceptions of natural character. Because human perceptions are affected by individual sensory acuity and a wide array of personal and cultural factors that can vary greatly between individuals (Chapter 3 & 8), and are subject to the "shifting baseline" phenomenon (Pauly 1995), it is not appropriate to measure and monitor changes in natural character using primarily community perceptions. An assessment of perceptions of natural character using "informed participants" has, however, contributed to the refinement of the QINCCE methodology (Chapter 8).

In summary, no existing New Zealand approaches would apply to all the different types of coastal environment and provide a quantitative methodology for measuring coastal natural character (and its change) as defined in Froude et al. (2010).

5.3 Analysis of potential methodological approaches for measuring and reporting coastal natural character and its change

Table 5.1 contains a set of criteria for assessing potential methodologies that may measure natural character and its change. Sources contributing to these criteria include: definition of natural character (Froude et al. 2010); criteria sets used to select national level indicators (Organisation for Economic Co-operation and Development 1993; Ministry for the Environment 1998 a,b; Advisory Committee on Official Statistics 2009); analyses of court decisions on natural character (Maplesden & Boffa Miskell(2000) and Chapter 4 of this thesis); the review of the New Zealand Coastal Policy Statement (Rosier 2004); development of environmental monitoring programmes (e.g. Froude 2002) and methodologies (e.g. Froude 2008); and the preparation of degree course material on environment monitoring and reporting (Froude 2006).

Table 5.1: Criteria against which potential methodologies for measuring natural character and its change are assessed

Criterion category	Criteria for methodology for measuring and reporting natural character and its change
Comprehensive	Addresses all components of the definition of natural character in Froude et al. (2010) and elements in New Zealand Coastal Policy Statement policy 13
	Addresses terrestrial, freshwater and marine coastal environments
	Provides for a variety of circumstances including broad scale and detailed assessments
	Addresses the spatial pattern of natural character variation
Consistent	Uses a consistent methodology framework across land-water boundaries and natural character discontinuities
	Developed within a consistent analytical framework
Flexible	Able to be used for a variety of purposes at a wide range of scales
Quantifiable	Uses directly-measurable, semi-quantitative (assessment against a baseline) and categorical data to facilitate measurement of change
Sensitive	Able to distinguish between human induced change and natural disturbance
	Responsive to environmental change
	Clearly distinguishes different levels of natural character

Criterion category	Criteria for methodology for measuring and reporting natural character and its change
Robust	Soundly based and well designed methodology
	Well- tested analysis and reporting framework
Practical	The data collection phase can be implemented by trained personnel but there is no requirement for a high level of specialist knowledge (especially in respect of taxonomy)
Transparency	The components that contribute to a natural character 'score' should be available for examination and other uses
Predictive capacity	Able to predict how the score would change in response to environmental change
Results understandable	Reporting addresses spatial pattern of natural character variation
	Reporting uses indices or equivalent to simplify the communication of complex information

5.3.1 Addressing natural character spatial patterns

The appropriate depiction of natural character spatial patterns is important for data collection, analysis and reporting (Table 5.1). Given the flexibility provided by GIS tools and the amount of data involved in most assessments, a methodology for measuring natural character and its change should include GIS technology.

Two distinctly different GIS approaches are possible. The first uses computer generated continuous classification based on continuous point or pixel data. "Units" may or may not be defined. This approach has been used to determine the boundaries in some spatial classification systems (e.g. Land Environments of New Zealand (Leathwick et al. 2003) and the New Zealand Marine Environment Classification (Snelder et al. 2005)).

Automatic computer classification (based on pan-sharpened ortho-rectified imagery with standardised spectral reflectance) was used by Ausseil & Dymond (2007) to classify four landscape attributes relating to wetlands in the Manawatu-Horowhenua Region. Spectral rules developed by Dymond & Sheperd (2004) were based on a decision-tree analysis framework for classifying various land covers. It would be very difficult to develop the type of spectral rules needed to use automatic computer classification to accurately classify the complex and diverse components of natural character. This is because a number of these components can not be assessed using aerial or satellite imagery (e.g. subtidal geomorphology changes, sound naturalness, darkness of the night sky); and it would be difficult to assess naturalness relative to baselines or reference conditions.

The manipulation of point-based datasets using GIS tools to define the boundaries of areas with particular types or levels of environmental value or threat (e.g. (Stephens et al. 2002) depend on large comprehensive databases and appropriate assumptions to address the often large data gaps. In the context of the diverse components that make up natural character this level of information is generally not available and the necessary assumptions in the absence of this information may undermine the utility of the methodology for measuring change.

The second GIS approach uses prior manual identification and delineation of units that contain relatively homogeneous levels of natural character (at the scale of assessment). The manually depicted unit boundaries are digitised and linked with an electronic database containing the unit attribute data. This approach is common in situations where boundary positions depend on complex interactions between different types of factors. Examples include the New Zealand Land Resource Inventory (Lynn et al. 2009) and a natural character framework for the Marlborough Sounds developed by McRae et al. (2004). The units in both of these examples may contain a high level of natural character variability because most of the factors used to define units are not major determinants of present levels of natural character and some important factors determining current natural character levels are not used. Having such heterogeneous units, from a natural character perspective, would reduce the sensitivity of a method that measures natural character change.

In a review of their two New Zealand trials to develop a method to measure the terrestrial landscape aspect of coastal natural character Boffa Miskell (2002a) recommended that units be defined using a geomorphological land classification based on coastal topology. In the absence of a national system they suggested sampling on a grid with each council using existing frameworks already used for purposes such as landscape assessment. These frameworks are often based on geomorphology (e.g. Whangarei District Council (1995)). Units depicted for landscape assessment or land system classification often contain considerable natural character variation, particularly in locations with a mixture of natural and cultural components. This high level of heterogeneity would hinder consistent measurements of natural character change.

Where manually depicted boundaries of "units" have been digitised future measurements could retain the same unit boundaries (as recommended in Boffa Miskell (2002b)). Alternatively, unit boundaries could be amended during future measurement periods where this is necessary to improve unit homogeneity. GIS tools can then be used to compare parameter measurements made in different time periods even where unit boundaries have been changed (Roger Smith, GeographX, pers. comm. 2009). The latter approach increases change detection capacity because the redefinition of unit boundaries each survey period (where needed because of environment change) allows the concept of "relative homogeneity" of units to be maintained over time.

It is proposed that relatively homogeneous units from the perspective of their current natural character be defined manually using information on factors that most directly affect current natural character levels. The boundaries would be digitised and the geo-referenced units linked to a database containing 'unit' attribute (parameter) data. GIS tools could be used to compare aggregated natural character change even where it is necessary to amend some unit boundaries to maintain relative natural character homogeneity of those units.

5.3.2 Using indicators and parameters

Natural character is a complex phenomenon. Like other complex phenomena (e.g. biodiversity) it is best assessed using a carefully selected set of indicators (and associated parameters) that can track changes in the main environmental components that comprise the natural character of an area. Parameters are either directly measured or derived from measured data.

The Pressure-State/Condition-Response framework has been widely used for developing and reporting indicators (Organisation for Economic Co-operation and Development 1993, 2003; Ministry for the Environment 2010). It is based on the concept of causality. *Pressures* (resulting from human activities) change the *State* or condition of the environment. Society's *Response* to these changes through environmental and other policies and actions forming a feedback loop to the pressures (Organisation for Economic Co-operation and Development 1993). The high level or aggregated indicator, *Amount of natural character* is a state/condition indicator. Specific indicators that represent components of natural character should ideally also be state indicators. Specific indicators selected for the QINCCE methodology are state indicators wherever possible. In situations where it is not practical to collect data about potential state/condition indicators surrogate pressure indicators are used instead.

There are many potential indicators (and associated parameters) that could be used to assess the state of natural character (using the definition in Froude et al. (2010)). In my analysis of 12 landscape-scale studies using GIS tools to manipulate digital data sets and/or data derived from remotely sensed imagery, the most common parameter measured (that was potentially relevant to natural character) was the area of each land cover class (e.g. (Dymond & Sheperd 2004; Walker et al. 2005; Ausseil & Dymond 2007; Levin et al. 2007; Taylor et al. 2007). Other parameters measured included: areas of land use types (e.g. (Zube et al. 1989; Ferman-Almada et al. 2001; Otto et al. 2007)), utility density (e.g. (Zube et al. 1989; Ferman-Almada et al. 2001; Brabyn 2005); property size (e.g. Brabyn (2005), rural house density (Ferman-Almada et al. 2001; Wagner & Gobster 2007), stream channel thalweg length and sinuosity (Wagner & Gobster 2007), population density (e.g. (Hock 2000)), and built area classes and distances (e.g. Levin et al. (2007).

Some studies have matched land cover classes to other digital data sets to calculate a range of derived parameters (e.g. Walker et al. (2005)). In a project to prioritise sites for wetland conservation in the Manawatu, New Zealand, Ausseil & Dymond (2007) used GIS tools to calculate four derived parameters for wetlands: representativeness (ratio of present day wetland area to the historic extent for each land environment), wetland area for individual wetlands, surrounding naturalness for each wetland (the extent of natural vegetation in a two pixel buffer zone around each wetland) and wetland connectivity.

There are many other parameters that are not readily measured from remotely sensed imagery or derived from existing data sets. This includes a variety of potential ecological naturalness parameters, as well as those addressing hydrological and geomorphological naturalness and the impacts of human structures. Some of these potential parameters are discussed in the next section on aggregating information from different parameters.

5.3.3 Aggregating information from different parameters

Obtaining an overall readily understood assessment of natural character requires that different types of information be combined. The reporting of complex environmental data from different parameters is often done by way of an index or indices. Indices are commonly used in New Zealand environmental monitoring. For example, Auckland Regional Council (Brad Scarfe, Auckland Regional Council, pers. comm.) uses the following freshwater indices: macroinvertebrate community index (MCI) (Harding et al. 2009) for monitoring more than 60 rivers and streams; the quantile index of biotic integrity (QBI) for monitoring fish distribution; stream ecological valuation (SEV); the ARC water quality index (Auckland Regional Council 2010); trophic lake index (Burns et al. 2000); and Lake Submerged Plants Index (Lake SPI) (Clayton & Edwards 2002).

Indices can be constructed in a variety of ways. The simplest approach is where each of the different attributes is scored using categories or classes (e.g. 0 to 5), and then the scores are added to give a single total score. This approach has been commonly used in New Zealand. Examples include: the Wetland Condition Index methodology where parameters are measured on a six-point scale (Clarkson et al. 2004; Clarkson 2010); the New Zealand sand dune and beach inventory where four attributes are measured on a scale of 0 to 5 and summed to give a total score out of 20 (Johnson 1992; Partridge 1992) and the cultural health index for streams and waterways where a variety of parameters are scored on scales from 1 to 5 (Tipa & Tierney 2003).

LakeSPI measures a number of submerged macrophyte parameters associated with New Zealand lake ecological condition (Clayton et al. 2002). The measured parameters are converted into integer categorical scores which have different scales (Clayton & Edwards 2002). This acts as an implied weighting for different parameters representing their importance in the summed scores.

The methodology developed by Stephens et al. (2002) for measuring conservation achievement used comprehensive electronic datasets to calculate five primary parameters representing pressures on "natural character". These calculated parameters were multiplied together to give an index ranging from 0 and 1. The parameters were multiplied rather than added because it was considered that they were not independent. No weightings were used.

Ausseil & Dymond (2007) used a variety of data sources to calculate four parameters or criteria, each with a score between 0 and 1. They carried out a sensitivity analysis to determine whether any of the parameters had a disproportionate effect on the aggregate score. This analysis indicated that the criteria were mostly independent and that the weighting of each of the four calculated parameters would be the main driver to balance the four parameters. They acknowledged that the weighting of each criterion was arbitrarily assigned a value of 1. This could be changed. The scores for each wetland were added together and the total score divided by 4 to give an overall score between 0 and 1.

An alternative approach was used by Machado (2004) to develop an index of naturalness which was applied to the Galapagos Islands and parts of the Canary Islands. Naturalness was assessed in units where boundaries were selected to give a consistent level of naturalness within the unit. The naturalness of a unit was scored using a scale where 0 equated to no naturalness and 10 was used when an area was thought to be completely natural. The scoring template was a table where the column headings listed a suite of characteristics (e.g. native biotic elements, pollutants, artefacts, physical alterations) and the rows summarised the state of naturalness for each characteristic. Where this index differs from many others is that the most common naturalness score for the different characteristics becomes the naturalness score for that unit. The individual scores are not summed or multiplied. A team of at least two or three ecologists score the units, and consensus-building methods such as the Delphi technique (Rixon et al. 2007) are used to achieve agreement. To ensure consistency, team membership remains the same during the course of a project. Machado (2004) emphasised the value of the reporting approach where the naturalness scores for the units in a project are combined in a colour-coded bar graph that shows the percentage of each naturalness score.

The approach taken by Machado (2004) was designed as a rapid assessment tool. It would not be particularly suitable for measuring naturalness change over time because the scoring system depends on consistent assessments by the same team of experts. In addition the iterative process used to derive the final scores means that it is not possible to track changes in particular components affecting naturalness. The use of colour-coded bar graphs and maps showing naturalness are useful reporting approaches although care is needed when they are reproduced in black and white.

Ferman-Almada et al. (2001) developed a natural environmental quality index for the coastal zone of San Quintin, Baja California, Mexico. Forty five environmental units were defined using hydrology, physiography, vegetation and land uses. Quantitative measures were made for four pressure, three state and two response indicators. These measures were normalised to a common scaling of 0 to 100 (best). Pressure, state and response indices were each calculated by summing the normalised scores of each of the relevant indicators. These three indices were combined using weighting designed to force the overall environmental quality/ naturalness score to depend most heavily on the state index. This is a robust approach for complex concepts. As will be discussed in the next section, the methodology is similar to that used in the QINCCE methodology although the topic, style of the indicators and what is measured are quite different.

Opham et al. (2003) described the use of GIS tools to quantify the ecological quality of habitat in a region using three indices: network cohesion index (relationships between habitat patches for a species); spatial cohesion index (integrates network cohesion values of the habitat networks for a species); and landscape cohesion index (integrates the spatial cohesion indices for a number of different species). The application of this method requires sufficient data to complete the network and spatial cohesion indices for a diverse range of species. Opham et al. (2003) promoted this approach as a way to avoid monitoring individual species abundance. However, in New Zealand the impacts of alien species mean that a focus on patch size and linkages would not be sufficient.

Many of the environmental indices that have been developed address aquatic environments. Pinto et al. (2009) reviewed a number of estuarine biotic indices that had been developed in various parts of the world for the purpose of assessing benthic/estuarine condition. Many of the indices were relatively site specific and Pinto et al. (2009) recommended that they be recalibrated when applied beyond the area of their development. They recommended that this recalibration includes the determination of appropriate reference conditions and changes to the formula coefficients as appropriate.

Astin (2007) described the development of an index (Basin-wide Index of Benthic Integrity B-IBI) to access the health of non-tidal wade-able streams across different jurisdictions in the Potomac River Basin, USA. A set of seven metrics or calculated parameters based on the macroinvertebrate fauna were summed to produce the final single number. A calibration data set was used to set condition thresholds, including reference and degraded states. An important feature was the use of data from different agencies including their reference sites to obtain a larger effective data set. In New Zealand, river and stream macroinvertebrate data are collected by a number of agencies and indices with thresholds (Stark et al. 2001; Stark & Maxted 2004, Stark & Maxted 2007a) have been developed.

While most of the marine aquatic indices are for soft bottom environments, Juanes et al. (2008) developed a Quality of Rocky Bottoms Index (CFR). This is based on the analysis of Bay of Biscay rocky coast seaweed (macroalgae) communities from intertidal to the shallow subtidal. The index sums four metrics: richness of characteristic macroalgae communities, total cover, presence opportunistic species and physiological condition of the macroalgae community. As with many other indices, thresholds based on data and expert judgement have been developed.

A number of the indices include thresholds as this assists with the clear communication of results to the public and decision-makers. Typically such thresholds are set using numerical data and communicated to others by the use of qualitative terms such as excellent, good, fair and poor for a system with four thresholds. Examples of such indices include the aforementioned Potomac Basin-wide Index of Benthic Integrity (Astin 2007), Water Quality Index (Canadian Council of Ministers of the Environment 2001; Auckland Regional Council 2010), the New Zealand Macroinvertebrate Community Index (MCI) for wadeable rivers and streams (with versions using quantitative data (QMCI) and semi-quantitative data (SQMCI)) (Stark et al. 2001a), and the New Zealand Macroinvertebrate Community Index (MCI) for soft-bottomed streams (in Auckland) (Stark & Maxted 2004). The Quantile Index of Biotic Integrity (Auckland Regional Council 2010) uses seven thresholds that represent how well the presence of native species of fish matches that predicted based on distance from coast and elevation.

5.3.4 Using indices to aggregate New Zealand natural character data

Scientific data can be complex and difficult for laypeople and decision-makers to understand. A variety of indices have been developed to make this type of information easier for non-specialists to understand.

While the data for different parameters could be reported directly, many people would find it difficult to quickly understand the overall implications of the data for all the parameters for each unit. Indices can: combine complex information about a range of parameters into a simple system that can be understood by the public and decision-makers; provide a way to integrate information about different types of parameters; and be used to identify or set thresholds or standards.

A common criticism of indices is that they lead to the loss of information. This can be addressed. Indices should be based on actual data, these data should systematically recorded (e.g. on spreadsheets), and it should be possible to obtain this underlying data if necessary.

None of the existing indices satisfactorily report natural character and its change, especially not in the New Zealand context as described in Froude et al. (2010). Machado's (2004) index of naturalness is not suitable because it depends on assessment by the same team of experts and uses a non-transparent iterative process for determining the naturalness index. The methodology used to compile the environmental quality index developed by Ferman-Almada et al. (2001) is closer to what would be suitable for measuring natural character in the New Zealand context. The QINCCE methodology shares common features with this methodology (2001) including: the use of indicators, quantitative measures, and the transparent integration of the measured or calculated results into an index. The methodology of Ferman-Almada et al. (2001) does, however, use a different suite of indicators to that which would be useful for measuring natural character in the New Zealand context and does not address aquatic environments. Another difference is that Ferman-Almada et al. (2001) use roughly equal numbers of pressure, state and response indicators (using the pressure-state-response model of indicator development (OECD 1998)) whereas the QINCCE methodology primarily uses state indicators (as the focus is to measure the state or condition of natural character).

In contrast to the environment type specificity of most indices discussed, indices for reporting natural character and its change in the New Zealand context, need to be applicable across a diversity of terrestrial and aquatic environments. These indices, either individually or collectively, need to incorporate the data from a diverse range of parameters. Baselines or reference conditions are needed to provide a common context for scoring a number of parameters.

There are a variety of approaches that can be used to construct an index. A simple and common approach is to add a series of categorical scores (which may or may not be based on measured data). This approach assumes that each parameter should have equal weighting (e.g. Clarkson et al. 2004) unless the parameters use different scoring ranges (e.g. Clayton & Edwards 2002). Sometimes weightings are used, although it can be difficult to determine a robust approach for doing this. Another approach is to multiply the parameter data (e.g. Stephens et al. 2002). This is useful when the parameters are not independent and the relative weightings are unknown.

Indices can be described as qualitative or quantitative. While quantitative indices include directly measured data, qualitative indices are typically based on categorical scoring (e.g. 1-5) and presence/absence information. The New Zealand macroinvertebrate community indices for soft and hard bottomed streams provide an illustration of the difference between qualitative, semi-quantitative and quantitative indices. These indices include MCI (Macroinvertebrate Community Index), SQMCI (Semi-Quantitative Macroinvertebrate Community Index) and QMCI (Quantitative Macroinvertebrate Community Index). These indices are based on the premise that different taxa of macroinvertebrates exhibit different levels of tolerance to enrichment/ poor water quality. Each taxon is assigned a score from 1-10 based on their tolerance of poor water quality. Different tolerance tables have been constructed for soft and hard bottom streams (Stark & Maxted 2007a). The qualitative MCI is calculated using presence -absence data and the taxon scores. The SQMI and QMCI both use the taxon scores but the SQMCI is calculated using five categories of abundance for the taxa present, while the QMCI uses actual count data for taxa abundance (Stark & Maxted 2007a).

Indices use different scoring ranges and may or may not be standardised in some way so that they are easier for lay people to understand. For example, the New Zealand index that uses aquatic macrophytes to assess lake ecological condition- LakeSPI (Clayton & Edwards 2002) - reports lake condition scores as a percentage (e.g. Froude et al. 2011).

In the context of indices for measuring natural character, it was considered that percentage scores should be used to simplify reporting. Different components of natural character were included in different sub-indices which can be combined into an overall natural character index. Standard protocols were used to construct the indices. This facilitates the comparison of results across different coastal environment types and locations.

Thresholds are used to assist the reporting of a number of indices. The objectives of thresholds must be clear and there needs to be a robust system for determining appropriate thresholds for particular indices. Descriptive terms are often used for reporting compliance or achievement of thresholds. In the context of the New Zealand macroinvertebrate community indices, the stream quality thresholds for the QMCI and SQMI (scores range between 0 and 10) are as follow: >5.99 excellent; 5.00-5.90 good; 4.00-4.99 fair; and < 4.00 poor (Stark and Maxted 2007a, b). Initially professional judgement was used to set thresholds. Later this was replaced by an objective procedure that used the statistical distribution of biotic index values at reference sites, combined with an estimate of the lowest practical index value, to set the thresholds between classes (Stark & Maxted 2007a).

While expert consensus has been an accepted approach to developing thresholds for tightly focused indices (Weisberg et al. 2008), this is likely to pose some challenges for a wide-ranging index.

5.4 The QINCCE methodology for measuring coastal natural character and its change

This methodology has been specifically developed to address the methodology requirements set out in Table 5.1. The same framework is used for the different categories of terrestrial and aquatic coastal environments. Units that contain relatively homogeneous levels of natural character are depicted manually on printed aerial/ satellite imagery or on bathymetric charts for the marine environment. These units are subsequently digitised as polygons with geo-referencing. The size of units and level of subdivision depends on the purpose of the measurement and information available. Each geo-referenced unit has a unique identifier that links it electronically to a database containing that unit’s parameter information.

The comprehensive definition of natural character in Froude et al. (2010) provided a framework for indicator and associated parameter selection. For each broad class of coastal environment there is a core set of parameters. The final score for each parameter is between 0 and 1 with each parameter being used in the calculation of one of the following three sub-indices for each unit:

- An ecological naturalness index
- A hydrological and geomorphological naturalness index
- A freedom from buildings and structures index

In these indices the core parameter scores are combined using multiplication except where they are clearly independent. The independent parameters in each index are directly measured percentage cover assessments adjusted to 0 to 1 scores. Within the formulae these "independent parameter scores are summed. The three sub-indices for each unit are multiplied to give an overall index of natural character that lies between 0 and 1. This can easily be expressed as a percent natural figure to assist user understanding. All index formulae were confirmed after extensive field testing (Chapter 9) and comparisons between "informed" participant scoring of their perceptions of natural character and objective assessments (Chapter 8).

The core parameters are based where possible on underlying measured data (e.g. % cover). Those parameters using categorical data are supported by comprehensive scoring tables (Chapters 6 and 7). Direct measures improve the sensitivity of the indices, as does the detailed guidance on scoring for parameters using categorical data. This approach differs from some ecological indices that use general categorical assessments as the first step for all parameters (e.g. (Partridge 1992; Clarkson et al. 2004).

Figure 5.1 provides a diagrammatic representation of the application of the basic methodology. In situations or locations where a more comprehensive measurement of a wider range of parameters is required, additional *Tier-Two* parameters are available. For detailed assessments in terrestrial and intertidal coastal environments, an oblique *Viewpoints* measuring system has been developed to be used in conjunction with the plan-view based methodology.

While the overall purpose of the QINCCE methodology is to measure natural character and its change, the methodology has been designed to address a range of management applications of particular significance to the New Zealand context (Box 5.1).

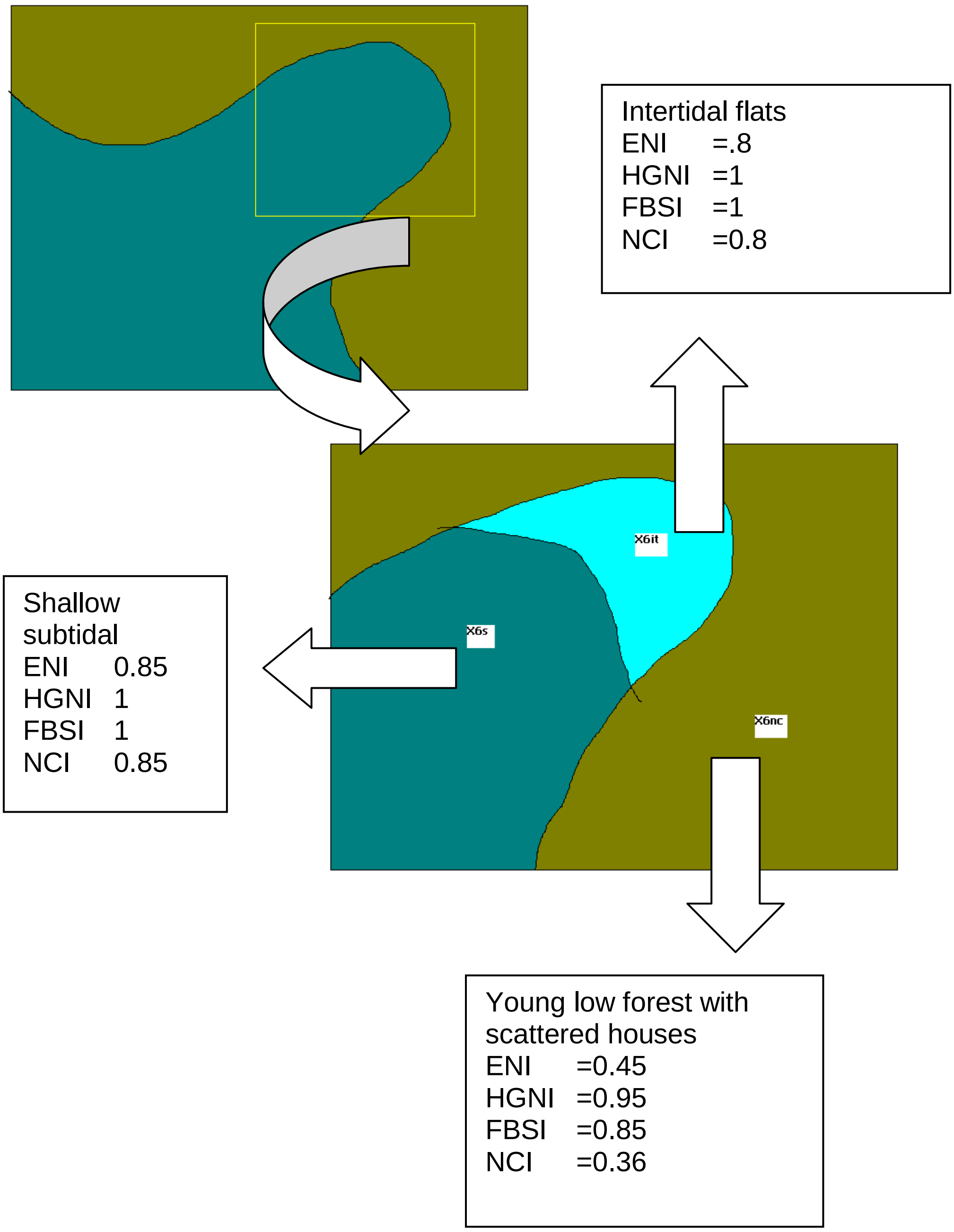

Figure 5.1: Diagrammatic representation of the application of the QINCCE methodology

Box 5.1: Potential applications for the QINCCE (Quantitative Index for measuring the Natural Character of the Coastal Environment) methodology

1. Measuring natural character and monitoring its change over time at a range of scales from a single “development” site to an extensive “length” of coast;
2. Measuring natural character and monitoring its change for different types of environmental systems. Examples of such systems could include: a large coastal embayment (e.g. Northland’s Bay of Islands), an island and its surrounding waters, or a geomorphological or hydrological system such as an estuary or coastal lake);
3. Monitoring change in the components of natural character via a suite of indices (ecological naturalness, hydrological and geomorphological naturalness, freedom from buildings and structures, and sound and light regime);
4. Providing a framework for “testing” or “predicting” potential natural character impacts of proposed developments;
5. Estimating potential coastal natural character outcomes that may result from decisions made under the Resource Management Act (e.g. particular Resource Management Act district or regional plan rules or a development proposal);
6. Monitoring natural character changes resulting from environment restoration programmes;
7. Providing a framework for evaluating natural character outcomes where there are temporal differences between the immediate adverse impacts of a development and the long-term mitigation benefits for large-scale planting of site-appropriate native species;
8. Providing a systematic framework for calculating the quantum of on-site or off-site mitigation works that may be required to offset the unavoidable adverse effects of an otherwise appropriate coastal development upon the natural character of a site.

5.4.1 Natural character units: boundary definition

Units that have relatively homogeneous levels of natural character are depicted manually and then digitised. Ortho-rectified aerial images are usually used for terrestrial, intertidal and, depending on image resolution, very shallow subtidal coastal environments. Marine bathymetry is usually used for defining unit boundaries in subtidal areas. Each unit is selected to be as homogeneous as possible from the perspective of the factors determining natural character and as appropriate for the scale at which the mapping and parameter assessment is being undertaken. In the marine environment a lack of information is likely to limit the intensity of units and the precision of boundaries in many locations.

In contrast to many landscape assessments and projects to identify "land-systems" (e.g. (Boffa Miskell Limited 2002b; McRae et al. 2004; Stephen Brown Environments 2008) the QINCCE methodology does not use geomorphology to determine boundaries. This is because geomorphology itself does not determine the level of natural character. Instead boundaries are defined using attributes that represent the level of natural character present. Key factors affecting the selection of terrestrial unit boundaries for the QINCCE methodology are: the proportion of native vegetation and/or natural surface, the land cover relative to the present-potential cover (definition in Box 5.2) for that site; and the density and scale of buildings/ structures and paved surfaces. A hydrological discontinuity may be used as a boundary, especially where this corresponds with a change in key factors affecting boundary selection.

There are elements of judgment and practice involved in the appropriate definition of boundaries. In some situations, especially where there is a mosaic of modifications caused by human activities and natural attributes, it may be difficult to determine the most appropriate unit boundaries.

Different protocols are used for determining the boundaries of aquatic environments. In general each coastal lake is a separate unit. This is the approach taken in other New Zealand lake assessment systems (e.g. LakeSPI (Clayton & Edwards 2002)). The lake-riparian margins are usually addressed as part of the adjoining terrestrial unit except where they are significantly different (e.g. margins that fenced and with native vegetation cover versus the grazed farmland beyond) and this is at a large enough scale to map. In some situations it may be appropriate to use more than one unit for a lake, especially if there are important differences in the naturalness of the cover. This may occur if there are large fluctuations in lake levels (giving a wide zone of periodically inundated land) or parts of the lake have very different characteristics.

Coastal streams and rivers are only mapped as separate units where they are sufficiently wide that they can be depicted as a separate unit at the scale of mapping. In practice the lower reaches of many rivers and streams will be separate units at more detailed mapping scales. Often their estuaries will be depicted as one or more units depending on their size and complexity. Key factors determining boundaries in estuarine intertidal environments are benthic or vegetation cover, and the density and type of structures.

Intertidal habitats on the open coast are rarely wide enough to be mapped in natural character assessments and are typically included with the adjoining subtidal unit. In general the subtidal environment will be more finely divided in shallow /near shore waters where there is more information from a variety of sources and where alien species, structures and human-induced hydrological and geomorphological changes are more likely.

Key factors affecting subtidal boundary depiction are the type and density of structures, presence of alien species; human-induced hydrological and geomorphological changes and areas where the local biota (versus pelagic) is not subject to human harvest pressure. As with the terrestrial approach the units depicted by McRae et al. (2004) contain considerably more natural character variation compared to those defined using the QINCCE system.

5.4.2 Alternative perspectives for assessing natural character

Two alternative perspectives (to the plan-view unit perspective) have been developed. It is anticipated that these will be used in more detailed assessments. The first is the oblique *Viewpoints* measuring system (section 6.6.1) has been designed to be used in conjunction with the plan-view based methodology for terrestrial and intertidal locations where more detailed measurement of natural character may be required. The same set of core parameters is used for both the plan and oblique perspectives, although the building /structure height parameter is not used in the *Viewpoints* measuring system.

A handheld or pole-supported grid is used to define an oblique *Viewpoint* "unit" for which percentage cover and other parameters are assessed. The protocols for using the grid are intended to match the human angle of view when neither head nor eyes are moved, and areas of peripheral vision are excluded. This central angle of view is what most influences perception of a scene and minimises distortion (Bockaert 2010).

A Shoreline assessment provides detailed information about the natural character of the narrow band of coast parallel to and straddling mean high water springs. It is most useful for those locations where natural character levels of the "shoreline" differ considerably from the terrestrial and/or aquatic units that this area is typically incorporated into as part of a standard plan-view assessment. Certain Tier-2 parameters, several "shoreline" specific parameters are measured in addition to the core parameters (section 6.6.2).

5.4.3 Indicators and parameters for measuring natural character

The comprehensive definition of natural character developed in Froude et al. (2010) provides a useful framework for selecting appropriate indicators for measuring natural character. The QINCCE indicators correlate well with the component parts of the natural character definition (Table 5.2).

Table 5. 2: Correlation of QINCCE indicators with the definition of natural character developed by Froude et al. (2010)

Definition component	QINCCE indicators associated with core parameters	QINCCE indicators associated with Tier 2 parameters
Part of nature, particularly indigenous nature	• Natural area, natural surface and biological artefact area cover • Impact of alien mammals on native flora and fauna (terrestrial & freshwater) • Progress to present-potential cover	• Alien plant pest cover
Free from the effects of human constructions	• Building, structure, paved or surfaced cover • Building & structure height/volume • Building colour naturalness & reflectivity (terrestrial and intertidal) • Alien cover on structures (subtidal)	• Non-natural sound risk & resilience • Artificial light
Exhibits fidelity to the geomorphology and hydrology of reference conditions	• Hydrological and geomorphic naturalness	
Exhibits fidelity to the biological structure, composition and pattern of the reference conditions chosen	• Progress to present-potential cover • Impact of alien mammals on native flora and fauna (terrestrial & freshwater) • Level of protection/ naturalness mobile biota (marine)	• Natural area and biological artefact area native cover • Status of indicator species that represent the state of naturalness • Alien plant pest cover
Exhibits ecological and physical processes comparable to reference conditions	• Hydrological and geomorphic naturalness (including water quality where a key driver) • Progress to present-potential cover	• Water clarity

Parameters are the specific measures that address high level indicators. Some parameters are directly measured (e.g. *% cover that is natural area/natural surface*) while others are derived or calculated (e.g. s*core for progress towards present-potential cover*). For definitions of special purpose terms used in some indicators and parameters see Box 5.2.

Box 5.2: Key special purpose terms used in the QINCCE methodology

Natural areas (NA) have vegetation or benthic cover (including marine encrusting fauna) and are where natural processes predominate. The species are not necessarily native and may include ecological pest plants and/or encrusting fauna. For the purposes of estimating percentage cover, natural area cover assessments in marine subtidal environments, include areas without obvious surface biotic cover as the bulk of the biota may be sub-surface fauna.

Natural surface areas (NS) do not have a readily visible biotic cover (e.g. very steep cliffs, highly mobile sands) and are where natural processes predominate.

Biological artefact areas (BAA) are where human management of the biota prevails. This human management is evident in the biological patterns and processes. Biological artefact areas include: agricultural, horticultural and forestry areas, orchards, vineyards, gardens, lawns and other areas of mown grasses.

Present-potential cover (PPC) for a site is the cover that would be present had humans and the introduced species they brought with them not arrived in New Zealand. It differs from historical vegetation /cover in that it incorporates the effects of geological, climatic disturbances and other natural changes that have occurred since human arrival and so is not necessarily the complex cover. This is addressed further in Chapter 7.

Present potential state (PPS) is the state or condition that would be present today had humans, their tools and technology and the introduced species they brought with them not arrived in New Zealand. This can apply to hydrology, geomorphology, vegetation and fauna. Extinct species are not included in PPS.

The definition of natural character (Froude et al. 2010) includes the concept of reference conditions. The reference conditions are generally *present potential natural state* (Box 5.2) and in the case of land or benthic cover, *present-potential cover* (Box 5.2). Reference conditions and the protocols for scoring *Progress to present-potential cover* are discussed further in Chapter 7 and Appendix 5.

5.4.4 Direct measures and categorical scoring

Several parameters assess the amount of cover within a unit. There are two main approaches to cover assessment. The first is a direct measure of percent cover; the second is to use cover-abundance classes. The latter approach is intended to speed up data collection. In botanical science a common cover-abundance scale is the Braun-Blanquet cover-abundance scale (Braun-Blanquet 1932) which uses six categories of unequal size. Others include: the Domin cover abundance scale (Hurford & Schneider 2006) which uses ten categories; and variants on the Braun-Blanquet system (e.g. Clayton & Edwards (2002)).

The QINCCE methodology uses percent cover for the terrestrial and intertidal units as this increases method sensitivity. This is because when cover classes are used any numerical analyses use the midpoint of the cover range for that class (Wilkum & Shanholtzer 1978). In addition, where the actual cover is close to a boundary between two cover-abundance classes, there is a high probability that it will be assigned to the wrong class, further decreasing the accuracy (Hurford & Schneider 2006).

Cover-abundance scales can be particularly useful in underwater environments where it is not generally possible to view all of the area being assessed. It is accepted that in some subtidal situations it may be necessary to use cover classes rather than direct measures of percent cover.

Categorical scoring is used for those parameters where direct numerical measurement is not possible (e.g. *building and structure colour naturalness score, score for progress towards present-potential cover*). The second of those parameters is derived from two assessments: the current cover and the present-potential cover. The relationship between the current cover and the present-potential cover is assessed using a 100 point categorical system (in practice usually only 20 categories are used) based on a log growth curve (Chapter 7). The assessment of building and structure height uses a similar system (Section 6.3.4).

5.4.5 Core parameters

Core parameters are those which are assessed for all units. They are used to calculate one of the following three indices:

- An ecological naturalness index (ENI)
- A hydrological and geomorphological naturalness index (HGNI)
- A freedom from buildings and structures index (FBSI)

While the core parameter set is basically the same for all coastal environments, there are some important differences for particular types of coastal environments (e.g. dunelands, estuarine intertidal, coastal lakes). In Table 5.3 the core indicators and parameters are arranged by sub-index. These parameters were selected after an extensive period of trialling (field and analysis options) in a variety of terrestrial and aquatic coastal environments.

Table 5.3: QINCCE methodology: core indicators and parameters arranged by sub-index

Ecological naturalness index (ENI)	
Indicator	**Parameter(s)**
Natural area, natural surface and biological artefact area cover*	• % cover natural area/100 • % cover natural surface/100 • % cover biological artefact area/100
Impact of alien mammals on native flora and fauna (terrestrial & freshwater)	Score representing the relative impact of/ freedom from alien mammal (terrestrial)/fish (freshwater) species on native flora and fauna for natural areas; natural surfaces; biological artefact areas
Level of protection/ naturalness mobile biota (marine)	Score representing the level of freedom/protection from human harvesting pressure for natural areas; biological-artefact-areas
Progress to present-potential-cover*	Score for *progress to present-potential cover* for natural areas; natural surfaces; biological-artefact-areas
Hydrological and geomorphological naturalness index (HGNI) HGNI=1-HGIS (Hydrological and Geomorphological Impact Score)	
Indicator	**Parameter(s)**
Hydrological and geomorphic impacts	• Score representing the magnitude of each human-mediated change to the hydrology and/or geomorphology compared to the *present-potential natural state* • % area affected by each human-mediated hydrological and/or geomorphological change
Freedom from buildings and structures index (FBSI) FBSI=1-BSIS (Buildings and Structures Impact Score)	
Indicator	**Parameters**
Building, structure, paved or surfaced cover	• % cover/100 buildings • % cover/100 structures • % cover paved, surfaced areas/100
Building & structure height/volume	• Score for maximum height (terrestrial or intertidal) of buildings; structures; paved • Score for structure volume (subtidal)
Building colour naturalness & reflectivity (terrestrial & intertidal)	• Score for colour naturalness of buildings; structures; paved • Score for reflectivity of buildings; structures; paved
Alien cover on structures (subtidal)	• Score representing the level of alien cover on structures only

*Descriptions of special purpose terms are in Box 5.2.

Chapter 7 contains the rationale and assessment protocols for the parameter *Score for progress to present-potential cover.* The rationale and assessment protocols for other core parameters are addressed in Chapter 6. This includes scoring protocols as follows:

- *Score for freedom from alien mammalian (terrestrial)/fish (freshwater) species as represented by measured condition and/or pest eradication/control strategy)(*Table 6.2)
- *Score representing the level of protection from human harvesting pressure (marine) (*Table 6.8)
- building and structure height (Table 6.5)
- colour naturalness and reflectivity scores for terrestrial and intertidal environments (Table 6.6)

In subtidal environments the colour naturalness and reflectivity of structures are not especially relevant since structures are rapidly covered by encrusting organisms unless antifouling paints are used and regularly reapplied. A major potential impact of structures in subtidal environments is that they provide a new surface that can be colonised by alien flora and fauna. This impact is not addressed in the ENI and is therefore included in the BSIS for subtidal environments only

The parameters for human-induced hydrological and geomorphological change address the magnitude of impact and the proportion of a unit affected by the impact. Table 6.3 contains the scoring system for on-site changes while Table 6.4 addresses the scoring for off-site impacts. The area affected by each change is estimated using ortho-rectified aerial images or marine charts, field inspection as required and other sources of information where these are available.

One core parameter that was rejected as a core parameter only at the end of the trial process (Chapter 9) was *Percentage native cover*. This parameter was initially retained for those environments where it could be relatively readily assessed because it was a direct quantitative measure and no work was required to determine the baseline of zero. It was subsequently rejected primarily because when both it and the parameter *score for progress towards present-potential cover* were included in the ecological naturalness index, this led to some double counting of the effect of introduced plant species. In addition, the parameter *Percentage native cover* could not be practically applied as a core parameter in all types of coastal environment. It is retained as a *Tier-Two* parameter and can be expanded to address each tier in multi-tiered forest and scrub communities.

5.4.6 Tier-Two indicators and parameters

In some situations (e.g. detailed assessments of development proposals) and areas (e.g. where a complex pattern of human influence has led to considerable natural character variation) the core indicators and the associated calculated indices may be insufficient on their own. In these cases *Tier-Two* parameters can be used to provide a more detailed measurement of natural character. Table 5.4 summarises these parameters by indicator. Details for *Tier-Two* parameters are in Chapter 6.

Table 5.4: QINCCE methodology: *Tier-Two* indicators and parameters

Indicator	Parameters
Native cover	• % benthic cover or vegetation canopy (and each tier for terrestrial forest and scrub communities) of natural area that is composed of native species • LakeSPI native index (lakes)
Status of indicator species that represent the state of naturalness	Presence & relative abundance* compared to baseline of: • ground dwelling birds, especially the New Zealand robin (*Petroica australis*) (terrestrial); • dotterels (*Charadrius obscurus, C. bicinctus*) (dunelands, sandy shores); • fernbird (*Bowdleria punctata*) (coastal wetlands & scrub); • reef heron (*Egretta sacra sacra*)(rocky coast, estuaries); • sea grass (sheltered intertidal and shallow subtidal); • horse mussels (*Atrina zelandica*) and snapper (*Pagrus auratus*) (subtidal estuaries & open coast soft sediment); • snapper, butterfish (*Odax pullus*), rock lobster (*Jasus edwardsii*), blue cod (*Parapercis colias*), kina (*Evechinus chloroticus*) (rocky coast subtidal) • % rocky coastline with mature healthy pohutukawa and/or puriri (*Vitex lucens*) compared to baseline
Alien plant pest cover	• % of natural cover that is alien pest species • LakeSPI invasive index (lakes)
Water clarity	• Maximum depth of continuous tall brown algae forest (>75% cover) (subtidal) • Maximum depth of flowering plants or characean meadows (coastal lakes) • Maximum depth seagrass meadows (sheltered waters)
Non-natural sounds	• Score representing risk of non-natural sounds • Score representing resilience to non-natural sounds
Artificial light	• Score representing risk of anthropogenic light

*Specific species listed are appropriate for the upper North Island, New Zealand and may be different elsewhere in New Zealand

Tier-Two parameters generally require higher resolution methodology than that used for the core parameters. The measurement of mobile indicator species (*status of indicator species that represent the state of naturalness)* requires repeat measurements using appropriate protocols to address seasonal migrations (e.g. snapper, rock lobster) and seasonal variability in conspicuousness (e.g. dotterel, kingfisher (*Halcyon sancta vagans*)). Replicate sets of quantitative data are needed for abundance estimates unless populations are so low and their visibility is sufficiently high that it is possible to undertake a census.

The native cover and alien pest plant cover indicators also require higher resolution methodology. While it is usually relatively straight-forward to estimate the percentage cover of native species for the canopy of forest and mature scrub vegetation using remotely sensed images and limited field checking, this is not the case for lower stature vegetation (e.g. grassland and low scrub species found on younger dunes) and aquatic benthic cover. In the case of lower stature terrestrial vegetation more detailed field inspection is needed and, depending on the level of accuracy required, quick quantitative measures (e.g. point- height intercept) may be appropriate. Quick quantitative methods (e.g. cylinder intercept method in Handford (2000) as modified by Froude (2008) for riparian vegetation) can be used to assess the percentage of native species in each tier for terrestrial forest and mature scrub communities. The same approach can be used to estimate the percentage cover by pest plant species. For lakes, the LakeSPI methodology can be used to measure the relative cover of native and alien species.

For marine soft sediments (excluding mangrove and saltmarsh areas), rocky and artificial hard surfaces (e.g. wharf and marina pilings) it can be difficult to assess the proportion of benthic cover that consists of native versus alien species. In general, marine benthic environments in harbours, estuaries and other sheltered waters are the most likely ones to contain alien benthic species. The risk is highest for those waterways where: vessels are stationary at a berth or at anchor, marine farm and infrastructure equipment is moved between waterways, and there are new surfaces such as wharves and jetties. Quantitative measures are generally required to assess percentage cover. It can be difficult to accurately identify the status of some marine invertebrate benthic organisms.

While parameters addressing non-natural sounds and night lighting are not difficult to assess using quick methods they can be site-specific, especially in areas with complex topography. Accordingly it is proposed that these parameters be implemented only at a detailed scale, especially where there is complex topography. They can be combined into a sound and light naturalness index.

5.4.7 Potential parameters not selected

Many potential parameters were considered and rejected. The rejected parameters discussed below include those that were potentially able to address issues that were identified during methodology development.

The area occupied by mangrove forest and scrub

In northern New Zealand some view the expansion of areas of mangroves as representing accelerated sedimentation that is destroying natural features such as sea grass meadows and sand flats (Morrisey et al. 2007). Recent increases in mangrove area are not necessarily due to accelerated sedimentation. Some increases are due to recovery after cutting (e.g. Haumi River) and some areas have responded to the removal of grazing pressure (e.g. Orongo Bay). Mangrove expansion may also reflect local changes in sedimentation patterns resulting from structures such as a causeway. In this case additional sediment may not be produced from the catchment but its pattern of deposition may have changed.

The rate of sedimentation

The measurement of this parameter would require special monitoring using in-situ plates or an equivalent methodology. Only a few rivers in Northland are currently measured this way and so this parameter could not be widely applied at this time. This may change in future.

Level of fragmentation of natural ecological associations in terrestrial coastal environments

It is not practical to measure this parameter at this time. Challenges that would need to be addressed before using this parameter include clarification of: what natural associations are being assessed for fragmentation; and at what scale fragmentation should be measured at. If fragmentation is measured at a scale that is larger than a mapped unit, it is unclear how the fragmentation results would be integrated with the unit based assessments for other parameters.

Level of visual contrast of biological artefact areas compared to the natural matrix.

This is primarily a visual amenity matter and is often addressed more generally in landscape assessments. It can be difficult to determine the boundaries of the natural matrix that the biological artefact area is to be compared with, especially when the same or similar non-native species to those found in biological artefact areas are also growing in the wild. Other reasons for rejecting this potential parameter are that it is not addressed in the definition of natural character, and the strongest visual contrast can be between different forms of biological artefact area (e.g. shelter belts of non-native tree species (often pines) on ridgelines surrounded by pasture composed of non-native species).

Status of indicator species (kereru) that represent the state of naturalness

The relatively widespread native bird species kereru (kukupa) was rejected for this *Tier-two* parameter. Kereru can be highly mobile as they search for suitable food. While they require mature native forest, they can be found in residential gardens where there is suitable food, particularly in winter. The presence of kereru does not mean that a specific site is highly natural. It does mean that the general area contains native forest of sufficient quality to produce food for kereru over much of the year (i.e. forests contain a variety of fruit bearing plants).

5.5 Analysis protocols for the core parameters

For each "plan-view" mapped unit, data from the measured and derived core parameters are used to calculate three sub-indices, each with a value from 0 to 1:

- Ecological naturalness index (ENI)
- Hydrological and geomorphological naturalness index (HGNI)
- Freedom from buildings and structures index (FBSI)

The next sections set out the formulae used to calculate these sub-indices which are multiplied to give the overall natural character index (NCI) for a unit. The NCI for a unit has a value between 0 and 1, where 0 represents no natural character and 1 represents an extremely high level of natural character. Data collected using the *Viewpoints* measuring system can be analysed in the same way as that collected using the plan view units. This is discussed in the context of the perception analysis in Chapter 8.

One matter still to be finally resolved for marine environments and coastal lakes is whether the natural character indices should be calculated for the water surface and column together, and then for the seabed. The alternative would be to separate the water surface calculations from those for the seabed and water column.

5.5.1 Ecological naturalness index

Formula 5.1 applies the environmental naturalness index for terrestrial and freshwater environments, while Formula 5.2 applies the environmental naturalness index to marine environments.

Formula 5.1: ENI formula for terrestrial and freshwater environments

$$ENI = \left((\%Ana \div 100) x\ PPCna\ x\ FASna\right) + \left((\%Ans \div 100) x\ PPCns\ x\ FASns\right) + ((\%Abaa \div 100)\ x\ PPCbaa\ x\ FASbaa)$$

Formula 5.2: ENI formula for marine environments

$$ENI = ((\%Ana \div 100)\ x\ PPCna\ x\ PHHna) + ((\%Ans \div 100)\ x\ PPCns\ x\ PHHns)$$

Where:

- *na = Natural area ,*
- *ns = Natural surface,*
- *baa = Biological artefact area*
- *%A = % Area*
- *PPC = Score for progress to present-potential cover*

- *FAS = Score for freedom from alien mammalian (terrestrial)/ vertebrate (freshwater) species as represented by measured condition and/or pest eradication/control strategy)*
- *PHH=Score representing the level of protection from human harvesting pressure/ naturalness of mobile biota populations (marine)*

The scores within each set of brackets in the ENI formulae are added because, for the purpose of the formulae, these scores are independent. If there are no natural areas, biological artefact areas or natural surfaces within a unit, the ENI for that unit will be zero. When the ENI for a unit is zero, the NCI will also be zero. If there is any doubt as to whether this is the case one of the three surface types addressed in the ENI will need to be assigned a nominal value greater than zero.

5.5.2 Hydrological and geomorphological naturalness index

The hydrological and geomorphological naturalness index (HGNI) is 1minus the hydrological and geomorphological impact score (HGIS) (Formula 5.3).

Formula 5.3: HGNI for terrestrial and aquatic environments

HGNI = 1-HGIS

$$\boldsymbol{HGIS} = \sum_{<1}^{>0} \boldsymbol{Mi}(\%\boldsymbol{Ai} \div \mathbf{100})$$

Where:

- *%Ai = % area affected by each hydrological and/or geomorphological change mediated by humans*
- *Mi= Magnitude of each hydrological and/or geomorphological change mediated by humans*

Comprehensive scoring tables have been developed (Chapter 6), and the formula constructed so that the HGIS for a unit cannot exceed 0.999. This prevents the HGNI for a unit being zero or less.

5.5.3 Freedom from buildings and structures index

The *Freedom from buildings and structures index* (FBSI) is 1 minus the buildings and structures impact score (BSIS) (Formulae 5.6 and 5.7).

Formula 5.6: BSIS for terrestrial and intertidal environments and the water surface

FBSI = 1-BSIS

$$\boldsymbol{BSIS} \; = \; [(\%\boldsymbol{Ab} \div \mathbf{100}) \; \boldsymbol{x} \; \boldsymbol{Hb} \; \boldsymbol{xNb} \; \boldsymbol{xRb}]$$

$$+ [(\%\boldsymbol{As} \div \mathbf{100})\ \boldsymbol{x}\ \boldsymbol{Hs}\ \boldsymbol{x}\ \boldsymbol{Ns}\ \boldsymbol{x}\ \boldsymbol{Rs}]$$
$$+ [(\%\boldsymbol{Ap} \div \mathbf{100})\ \boldsymbol{x}\ \boldsymbol{Hp}\ \boldsymbol{x}\ \boldsymbol{Np}\ \boldsymbol{x}\ \boldsymbol{Rp}]$$

Formula 5.7: Provisional BSIS for subtidal environments

$$\boldsymbol{BSIS} = [(\%\boldsymbol{As} \div \mathbf{100}) \times \boldsymbol{Vs} \times \boldsymbol{Is}] + [(\%\boldsymbol{Ap} \div \mathbf{100}) \times \boldsymbol{Vp} \times \boldsymbol{Ip}]$$

Where:

- *b = Buildings,*
- *s = Other Structures,*
- *p = Paved and hard surfaced areas*
- *% A = % Area*
- *H = Height score or V=Volume score*
- *N = Colour naturalness score*
- *R= Reflectivity score*
- *I=Introduced species on structures and surfaces cover score (underwater)*

The results of the calculations for each of the square brackets in the BSIS formula are added because for the purpose of the formula they are independent. Buildings are not included in the subtidal formula. If there are very different types of structures an additional structures bracket could be added into Formula 5.7. Further work is required to fine-tune the BSIS formula for the water surface. The perception study (Chapter 8) indicated that it would be appropriate to include a weighting for either the BSIS or its individual components.

5.5.4 Natural character index

The processes leading to the formula for natural character index (NCI) are described in Chapters 2, 8 and 9. The natural character index formula (Formula 5.8) does not include weightings but the sub-indices are multiplied together as the three sub-indices are not entirely independent. The NCI for a unit lies between 0 and 1, where 0 means that no natural character remains, and 1 is where the unit has an extremely high level of natural character.

Formula 5.8: Natural character index (NCI)

$$NCI = ENI \times HGNI \times FBSI$$
$$0 < NCI, ENI, HGNI, FBSI \leq 1$$
$$NCscore = NCI \times 100$$

5.6 How well does QINCCE address the methodology criteria?

Table 5.1 contains a set of criteria for assessing the utility of methodology for measuring natural character and its change. Table 5.5 summarises how each of the criteria are addressed by the QINCCE methodology.

Table 5.5: How well does the QINCCE methodology address the criteria for methodology for measuring natural character and its change?

Criteria	How each criterion is addressed by QINCCE methodology
Addresses all components of the definition of natural character in Froude et al. (2010) and elements in New Zealand Coastal Policy Statement policy 13	All components of the natural character definition are addressed as specified in Table 5.2. The elements in New Zealand Coastal Policy Statement policy 13 are addressed in core and Tier-Two parameters. Environmental components that provide experiences are addressed
Addresses terrestrial, freshwater and marine coastal environments	The methodology framework is used for terrestrial, freshwater and marine environments with some parameter variation for different types of coastal environment.
Provides for a variety of circumstances including broad scale and detailed assessments	Core methodology can be expanded through the use of additional parameters if required. Different assessment perspectives are available
Addresses the spatial pattern of natural character variation	Units of relatively homogeneous levels of natural character are depicted manually, digitised and linked with parameter data. GIS tools used to enhance sensitivity to detect change
Uses a consistent methodology framework across land-water boundaries and natural character discontinuities	Consistent framework used for terrestrial, freshwater and marine environments. Core parameters are standardised to the extent possible.
Developed within a consistent analytical framework	Methodology has been developed within a consistent framework with indicators, parameters derived from a comprehensive definition of natural character in the context of the pressure-state-response model (Organisation for Economic Co-operation and Development 1993)
Able to be used for a variety of purposes at a wide range of scales	Methodology can be used at different scales and for a variety of purposes (Box 5.1). *Tier-two* parameters can be used where more detail is required.
Uses directly-measured, semi-quantitative (assessment	Parameters are directly measured (e.g. % cover), or scored in categories (directly or as a

Criteria	How each criterion is addressed by QINCCE methodology
against a baseline) and categorical data to facilitate measurement of change	derived assessment)
Able to distinguish between human induced change and natural disturbance	*Present-potential state* reference conditions used for some ecological and hydrological and geomorphological parameters. *Present-potential state* distinguishes between natural and human induced disturbance
Responsive to environmental change	To improve sensitivity: parameters use nearly continuous measures or clearly defined multi-step categories; and natural character unit boundaries can be revised over time
Clearly distinguishes different levels of natural character	Case studies clearly distinguished many levels of natural character. A future item of work could be to develop the process for determining thresholds in different coastal environment types
Soundly based and well designed methodology	Methodology has been developed after extensive analysis of alternative approaches and testing of options
Well- tested analysis and reporting framework	Analysis framework has been tested and revised through case studies and a perception study. Reporting framework based on indices
The data collection phase can be implemented by trained personnel but there is not a requirement for a high level of taxonomic knowledge	Those collecting data require ecological skills and experience and knowledge of local ecosystem (including hydrological and geomorphological) changes and current patterns. A detailed knowledge about taxonomy is not required.
The components that contribute to a natural character 'score' should be available for examination and other uses	A suite of measured parameters provides transparency (compared to a single overall expert assessment) and facilitates repeat measurements. Individual parameter data is available for other uses
Able to predict how the score would change in response to environmental change	It is possible to use alternative parameter data in natural character formulae to test/ predict natural character outcomes.
Reporting addresses spatial pattern of natural character variation	Reporting uses aerial images or maps with unit boundaries. Natural character scores can shown for each unit
Reporting uses indices or equivalent to simplify the communication of complex information	A set of indices, including an overall natural character index, is used for reporting. These indices simplify the reporting of natural character

5.7 Conclusion

The QINCCE methodology for measuring coastal natural character and its change provides a consistent framework for terrestrial and aquatic environments based on the measurement of parameters (linked to indicators) within spatial units. Actual and derived parameters are combined into three sub-indices and an overall natural character index. The methodology has been most thoroughly developed and trialled for terrestrial and estuarine intertidal environments. More work is needed to refine: the procedure for defining the boundaries of subtidal units; and the protocols for measuring some subtidal parameters.

The QINCCE methodology has been developed in Northland Region using case studies for Northland's east coast (Chapter 9). The methodology framework and parameters apply nationally. In other parts of New Zealand the detailed scoring protocols for the parameter *Progress towards present-potential cover* (Chapter 7) are likely to need some adapting to address local variation in *present-potential cover* and succession pathways and timing.

The methodology has been designed to measure coastal natural character in the New Zealand context. This context recognises the relatively short time of human occupation and impact compared to other major land masses where alternative types of reference conditions could be required for some indicators (especially *progress towards present-potential cover* and *hydrological and geomorphological naturalness*). The methodology could also be applied to other countries/regions that have been subject to relatively recent human settlement where pre-human settlement baselines can be determined. It can also be readily extended to non-coastal environments in New Zealand and elsewhere. The methodology used to determine the QINCCE natural character index and associated sub-indices is internationally unusual in that it provides a quantitative integration of parameters measuring a diverse range of attributes that contribute to or detract from natural character in both terrestrial and aquatic environments.

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6 QINCCE methodology parameter derivation and measurement

Abstract

This chapter contains descriptions of the rationale and methodology for the core and *Tier Two* parameter s for the Quantitative Index for measuring the Natural Character of the Coastal Environment (QINCCE) methodology. The core parameters contribute directly to the natural character indices. *Tier-Two* parameters can be used in situations where more detail is required. Terrestrial and marine environments are addressed for both core and *Tier –Two* parameters.

6.1 Introduction

Chapter 5 described the rationale and overall methodology for measuring natural character. This chapter provides the detail for each of the core and *Tier-Two* parameters for terrestrial and marine coastal environments. The core parameters are assessed in all situations where the QINCCE methodology is applied. Each core parameter is used in one of the three natural character sub-indices that are combined into the overall Natural Character Index (NCI) for each assessed unit.

Tier-Two parameters are available for use in situations where more detailed assessment is required (e.g. coastal development resource consent application). These parameters also use either direct measurements or category scoring but their amalgamation into indices is not fully developed at this time. An index is available for sound and anthropogenic light.

6.2 Percent cover parameters

The parameters that measure percent cover are collectively comprehensive and mutually exclusive. This means that all of a unit is to be assigned to a cover category and no part is to be assigned to more than one category. These parameters are directly measured. The reasons for the selected suite of cover parameters are:

- The suite is comprehensive without being impractically large (although a cover category could be subdivided as part of a detailed assessment);

- The methodology development trials (Chapter 2) found that the current selection of cover parameters (when combined with the specific parameters in the Ecological Natural Index (ENI) and the Buildings and Structures Impact Score (BSIS)) provide a good level of precision for natural character assessments. In some units a smaller set of cover parameters may lead to inappropriate data aggregation for some of the associated parameters.

In practice most mapped units include a subset of cover categories. The first three cover categories in Table 6.1 contribute to the ENI, while the last three categories contribute to the BSIS and subsequently the Freedom from Buildings and Structures Index (FBSI).

The percent cover assessments for each mapped unit total 100% with no area assigned to more than one cover category. For each cover category, the percent cover number is divided by 100 to give a score between 0 and 1 that is used for calculating the natural character sub-indices. The description of each cover category (Table 6.1) is to assist with method application. The cover categories do not need to be rigidly applied, although it is essential that there be no confusion with cover estimates contributing to, for example, the ENI rather than the BSIS. Each of the ENI cover categories are multiplied by the same parameters (albeit with different scoring). The same applies to those cover categories contributing to the BSIS and subsequently the FBSI.

Table 6.1: Description of cover categories used in the percent cover parameters

Cover category	Description of cover category
Natural surfaces (for terrestrial and intertidal environments)	No readily visible biotic cover (e.g. very steep cliffs, highly mobile sands). Natural processes predominate
Natural areas	In terrestrial and intertidal areas these are vegetated areas where natural processes predominate. The species are not necessarily native and may include ecological pest plants. In the subtidal environment this includes areas with and without obvious surface biotic cover
Biological artefact areas	Human management of the biota prevails. This is evident in the biological patterns and processes. Biological artefact areas include: agricultural, horticultural and forestry areas, orchards, vineyards, gardens, lawns and other areas of mown grasses. They also include large-scale newly planted sites for ecological restoration

Cover category	Description of cover category
	purposes where natural patterns have not yet established. This category is of limited extent in the marine environment, although it could include areas subject to intensive beach grooming.
Buildings	A subcategory of structures which includes commercial premises, factories, warehouses, residential dwellings, sheds, garages
Structures	All other structures of any type. In practice this is applied at a scale that is appropriate for the project/scale of mapping
Paved, surfaced and tracked areas	Compaction and/or sealing restricting water percolation into the soil/groundwater. This includes paving and sealing of all types, the application of road metal to sealed or unsealed roadways. In dunelands this category includes un-surfaced tracks.

Where possible, percent cover estimates for buildings, structures, paved and surfaced areas in terrestrial environments should be adjusted to remove the effects of overhanging vegetation on these estimates. This is because the overhanging vegetation is usually a thin screen over a substantially altered ecosystem underneath. Percent cover estimates for un-surfaced tracks typically only include those tracks that are clearly visible and not covered by overhanging vegetation. This is because narrow un-surfaced tracks under a dense forest canopy tend to have a lower ecological impact and can be difficult to detect on satellite or aerial imagery. In contrast, vehicle and foot tracks in dunelands often damage vulnerable vegetation, can affect dune stability and can usually be detected on aerial photographs.

6.3 Ecological naturalness parameters

In terrestrial and intertidal environments each of the adjusted percent cover scores is multiplied by a score for each of following first two parameters. For marine environments each adjusted percent cover score is multiplied by a score for each of the first and third parameters:

- Score for progress towards *present-potential cover* (all coastal environments)
- Score representing the relative impact of alien mammal/fish species on native flora and fauna (terrestrial and freshwater environments)

- Score representing the level of protection from human harvesting pressure (marine environment only)

The rationale and methodology for the first parameter is described in Chapter 7. In the context of the pressure-state-response indicator model (OECD 1998) this is a ‘state’ indicator. The other two ecological naturalness parameters are ‘pressure’ indicators.

6.3.1 Relative impact of alien mammal/fish species on native flora and fauna

This is a pressure indicator for terrestrial and freshwater indigenous wildlife as well as the condition and regeneration of many indigenous plant species and communities. A pressure indicator is used because it is not practical to use rapid assessment methods to determine the state of indigenous wildlife and the state and regeneration of indigenous plants. The parameter is *Score representing the relative impact of alien mammal/fish species on native flora and fauna.*

At the time of human arrival in about 1280 (Wilmshurst et al. 2008), New Zealand was distinctive in having no mammals apart from several species of bat and having terrestrial ecosystems dominated by avian herbivores rather than the more usual mammalian herbivores. Lee et al. (2010) proposed several pre-settlement distinctive avian-mediated vegetation types (including a coastal herb-rich low-forest-scrubland) and reductions in the relative proportions of many broadleaved species. Since human settlement 50% of endemic avian herbivore species have become extinct, but the mammalian herbivores that replaced them in recent times are not ecologically equivalent. Indigenous avian herbivores favour the persistence of indigenous vegetation while mammalian herbivores continue to induce declines in certain plant species, change regeneration patterns and favour the spread of introduced plant species (Lee et al. 2010).

All of the Holocene (last 10,000 years) bird extinctions are thought to have occurred after human arrival in New Zealand, with human-hunting being the leading cause of extinctions (Tennyson 2010). This was followed by predation by rats, cats and other introduced species and loss of prey for raptors (Tennyson & Martinson 2007). Researchers blame the extinctions of native frog, lizard and bat species primarily on rat predation (Tennyson 2010). A comprehensive review by Innes et al. (2010) found that predation by introduced pest mammals continues to be the main reason for current declines and limitations of New Zealand forest birds at the national level. In some regions the loss of forest is primarily responsible for the forest bird decline or extinctions (Innes et al. 2010) and habitat restoration is needed before forest birds can re-establish there.

Introduced fish species are present in most coastal rivers and lakes. Salmonids can cause trophic cascades that result in increased algal biomass and changes to energy and nutrient fluxes in rivers and streams (Simon & Townsend 2003). In lakes their feeding behaviour can shunt nutrients from the littoral to the pelagic zone thereby stimulating phytoplankton production. In streams they alter the behaviour of grazing invertebrates that suppress phytoplankton (Simon & Townsend 2003). Some other species of introduced fish have an even more damaging impact on freshwater ecosystems (Chadderton 2003; Koehn 2003). A Department of Conservation hosted workshop assessed invasive freshwater fish species using seven criteria addressing potential ecological impacts, economic impacts, dispersal ability, fecundity and environmental tolerance. The top six species of those already present in New Zealand ranked as posing the greatest threat were in order: koi carp (*Cyprinus carpio*), catfish (*Ameiurus nebulosus*), rudd (*Scardinius erythrophtbalmus*), perch (*Perca fluviatilis*), brown trout (*Salmo trutta*) and mosquitofish (*Gambusia affinis)* (Chadderton et al. 2003).

New Zealand's galaxiid fishes have special features that make them the aquatic equivalent of New Zealand's unique bird fauna (McDowall 2010). Galaxiids (Galaxxidae) make up most of New Zealand's indigenous fish fauna (McIntosh et al. 2010). Most species are endemic and at least 65% of New Zealand galaxiid species are regarded as threatened (Hitchmough et al. 2007). The majority of distributional data implicates the almost ubiquitous trout in the decline of many galaxiid populations with predation being one of the main drivers (McIntosh et al. 2010). Relative size is a key factor, with all non-diadromous galaxiids (maximum size 90-150mm (McDowall 2000)), juveniles and smaller diadromous fish being vulnerable to trout predation (McIntosh et al. 2010). Trout may also adversely affect galaxiid behaviour, and the abundance and behaviour of stream invertebrates which are the main food of galaxiids (McIntosh et al. 2010).

The parameter *Score representing the relative impact of alien mammal/vertebrate species on native flora and fauna* is assessed using categories that represent the status of introduced mammal species(for terrestrial environments) or introduced vertebrate species (for freshwater environments) as well as the level of control of these species. The score ranges from 1 when all alien mammal/vertebrate species are absent to 0.7 when there is no control of alien mammal/vertebrate species (Table 6.2). This scoring uses categories that address known absences and the type and intensity of introduced mammal management. As a core indicator only four levels are provided but this could be expanded in more detailed assessments.

Table 6.2: Scoring system for the parameter *Score representing the relative impact of alien mammal)/fish species on native flora and fauna*

Score	**Known levels of alien mammal /fish species**	**Intensity of alien species control/eradication programmes**
1	Alien mammalian species absent (e.g. the islands and rock stacks of the eastern Bay of Islands excluding an area of sheep grazing on Urupukapuka Island) Introduced fish species are absent from coastal lakes and rivers	Alien mammalian species have been removed by a comprehensive pest eradication programme
0.9	Regular monitoring shows that alien vertebrate pest species are kept at very low numbers and some of the key damaging species are absent “Pest fish” (rudd, perch, koi carp, tench and gambusia) are absent from coastal lakes and rivers and native fish are present in good numbers	There are comprehensive multiple pest species control programmes (e.g. Russell and Cape Brett Peninsulas in the Bay of Islands)
0.8	It has not been demonstrated that vertebrate pest species are at a sufficiently low level to significantly benefit native wildlife and vulnerable native plant species One or more pest fish species is present in coastal lakes or rivers	There is a low level of control of introduced vertebrate [pest] species and/or only one of a number of pest species is being controlled
0.7	Introduced vertebrate species	There is no control of alien

Score	Known levels of alien mammal /fish species	Intensity of alien species control/eradication programmes
	are present in high numbers and they are likely to be causing significant damage to native flora and/or fauna. Introduced fish species dominate and few if any native fish are present in coastal lakes and rivers	vertebrate species. Domestic stock are not excluded from natural areas

6.3.2 Level of protection from human harvesting pressure/ naturalness of mobile biota populations (marine)

The dramatic impacts of human harvest activities on marine ecosystems have been described by a number of particularly northern hemisphere authors (e.g. (Pauly et al. 1998; Jackson 2001; Jennings & Blanchard 2004). Heavy fishing of favoured fish species leads to losses of top predators from many ecosystems (Pauly et al. 1998), changes in marine food webs (Christensen & Richardson 2008; Heithaus et al. 2008), relative increases in prey species with consequential impacts on other parts of the marine ecosystem (e.g. increases in urchin barrens) (Babcock et al. 1999) and population structure changes and instability in fished species (Anderson et al. 2008). Conversely the establishment of a sufficiently large no-take marine reserve over time leads to: a series of ecosystem changes (Babcock et al. 1999; Shears & Babcock 2003); increases in formerly exploited species (Pande et al. 2008); and an ecosystem that more closely represents a "natural" un-fished state.

The parameter *Score representing the level of protection from human harvesting pressure* is assessed using categories representing the level of protection from human harvesting pressure and therefore the relative naturalness of mobile biota populations. The score ranges from 1 when where there has been no harvesting for more than 15 years, to 0.7 when there are standard New Zealand controls on fisheries harvest (Table 6.3).

The reason for differentiating between areas that have had long-term controls preventing harvest versus those that have had such controls in place for a shorter time is that marine reserve monitoring programmes have shown that the biota takes some time to "recover" from the removal of fishing pressure (Pande et al. 2008). The response time varies considerably between species and is influenced by factors such as marine reserve size (Taylor et al. 2011 in prep). In a global analysis of 1000 ratios of fish densities inside and outside of marine reserves Molloy et al. (2009) found that reserves older than 15 years consistently harboured more fish compared with unprotected areas. It may be appropriate to refine the scoring system to distinguish between different sizes and locations of marine reserves. As a core indicator, only four score levels are provided but this could be expanded in more detailed assessments.

Table 6.3: Scoring protocols for level of protection from human harvest

Score	Level of protection from human harvesting pressure	Relative naturalness of mobile biota populations
1	No harvesting has been permitted for 15 or more years (e.g. Cape Rodney-Okakari Point Marine Reserve)	Relatively natural local reef/ soft sediment fish and invertebrate populations (provided that the reserve is sufficiently large)
0.9	The provisions prohibiting harvesting have been in place for less than 15 years	Relatively natural local reef/ soft sediment fish and invertebrate populations are becoming more natural (provided that the reserve is sufficiently large)
0.8	There are very strict controls on the harvest methods and/or types of organisms that can be harvested. Typically no commercial fishing is allowed and recreational fishing is strictly controlled	At least some of the harvestable reef/ soft sediment fish and invertebrate populations are more natural/ less impacted by human harvest than other similar areas
0.7	Standard New Zealand controls on harvesting methods, extraction rates, and quotas	This is the typical state for harvestable fish and invertebrates where the maximum sustainable yield regime requires all populations to be harvested to between 15-20% of virgin biomass

6.3.3 Hydrological and geomorphological naturalness parameters

Hydrological (including hydraulic) and geomorphological naturalness is assessed relative to *present-potential natural state*. P*resent-potential natural state* is that which could be expected today had humans and their technology not arrived in New Zealand but natural processes/ disturbances had occurred (sections 7.3.2 and 7.3.3).

Hydrological (including hydraulic) and geomorphological naturalness is assessed for terrestrial and aquatic environments using the following two parameters:

- *The score representing the magnitude of each change to the hydrology and/or geomorphology compared to the "present-potential natural state"*
- *% area affected by each hydrological and/or geomorphological change*

The changes referred to in these parameters are those mediated by humans and their activities. There are many types of human-mediated change to natural hydrology and geomorphology in coastal environments (e.g. Suren & Elliott (2004); Reid et al. (2008); Campbell (2010)). Human-mediated changes to hydrology and geomorphology may be closely associated. For example, dune flattening removes dune swales with the associated wetlands and lakes; while bulldozing a river mouth to a different location affects both hydrological and geomorphological states and processes.

Few examples were found of literature that provided detailed guidance on appropriate scoring protocols for hydrological and geomorphological naturalness. The first New Zealand Coastal Policy Statement (NZCPS) (Minister of Conservation 1994) specified thresholds for 'restricted coastal activities' (RCA) in the coastal marine area for which the Minister's consent was required. These thresholds were a mixture of the type of activity and its magnitude. Those thresholds (which are not included in the second NZCPS (Minister of Conservation 2010) did not provide a suitable basis for scoring on-site impacts (Table 6.4) because: the hydrological and geomorphological naturalness parameters separate the assessment of the magnitude of a change from the proportion of the unit affected by that change; more than a single threshold is required; and terrestrial impacts were not addressed in the RCA thresholds.

Another source of potential guidance was the methodology for monitoring New Zealand wetland condition (Clarkson et al. 2004). This methodology treats a wetland as a single entity and uses a six-point scale to score a number of parameters related to wetland condition. The parameters that address wetland hydrological naturalness are:

- Impact of man-made structures that alter the hydrological regime
- Change in water table depth

Both of these parameters integrate the magnitude of change with the amount of wetland affected. In contrast the QINCCE methodology separates the magnitude of the impact and the amount of a unit affected. Clarkson et al (2004) use several physiochemical parameters including:

- Degree of sedimentation/erosion
- Nutrient levels

One option given for measuring the first parameter would be to use water clarity standards. This is consistent with the approach of the QINCEE magnitude parameter but not one that could be directly transferred to the wider coastal environment in a way that would be practical as part of a quick assessment. The other option used for measuring the first parameter in Clarkson et al. (2004) is an assessment of visible sedimentation and erosion/scouring. As with the hydrology parameters this assessment addresses how much of the wetland is affected and so integrates the magnitude of impact with the amount of wetland affected.

Clarkson et al. (2004) also include several relevant pressure indicators as follows:

- Modification to catchment hydrology
- Water quality within the catchment

Both of these are assessed on a six-point scale. The first uses the amount of the catchment subject to hydrological modification while the second suggests the use of macro-invertebrate indices (e.g. Stark et al. (2001)). The QINCCE methodology avoids the use of pressure indicators except where there is no practical alternative. Given the large variety of potential pressures affecting the varied hydrology and geomorphology in the coastal environment, state indicators are preferred.

An indigenous people's or Maori approach to the assessment of wetland condition (Harmsworth 2002) includes matters relating to hydrological and geomorphological naturalness within a broad indicator of *te Mauri* (life-force or life-element of the wetland system). There are no scoring protocols, and given the complexity of the concept mauri, this approach could not be used to guide scoring for hydrological and geomorphological naturalness.

The geomorphic condition of several Auckland streams was assessed using four geo-indicators where the parameters were a series of structured questions to which the answer would be either yes or no (Reid et al. 2008). The number of 'yes' answers for each indicator were summed and standardised to address different numbers of questions for each indicator. The summed standardised scores for all indicators were converted into percentages with thresholds for poor, moderate and good condition. This approach does not readily translate into that used in the QINCCE methodology and is for a limited range of the systems encompassed within the coastal environment. However, it provides guidance for the scoring protocols relating to rivers and their floodplains.

Table 6.4 provides provisional magnitude-of -impact scoring protocols for on-site changes. As many types of changes can occur at very different levels of magnitude (e.g. cut-and-fill earthworks) some types of human-mediated change are divided into different scoring categories. Further work is required to refine this table.

Given the large variation in the scale and types of human-mediated changes to hydrology and geomorphology in different types of coastal environments, the magnitude-score for some types of impacts/changes is given as a range. The sizes of the ranges in Table 6.4 vary, reflecting considerable variation in the magnitude of the impact for some types of change. As would be expected where the impact of a change is at the lower end of possibilities, then the score should be at the lower end of the range. The data collection form (Appendix 4) provides space for a brief description of each change in hydrological and/or geomorphological state for a mapped unit. This can be used to assist any revision of scores when more information becomes available.

The proportion of the unit affected by each change is measured as percent cover. As with the percent cover parameters (section 6.2), the percent-cover measurement for each hydrological and/or geomorphological change is divided by 100 to give a score between 0 and 1 that is used in the formula used to calculate Hydrological and Geomorphological Impact Score (HGIS) for a mapped unit.

There needs to be separate treatment of the hydrological and geomorphological impacts caused by offsite activities and structures. This includes the impacts of: upstream/up-current/ downstream/down current structures and other human activities; catchment vegetation removal; and human-mediated changes in catchment permeability. Scoring the impacts of on-site hydrological and geomorphological changes resulting from human actions at another location can be difficult as impacts can vary depending on the scale of the human activities (at the other location) and the attributes of particular sites.

The impacts of off-site activities on hydrological and geomorphological naturalness have been included in several indices (Clarkson et al. 2004; Reid et al. 2008) although the basis for scoring is different as previously discussed. Table 6.5 sets out the provisional scoring protocols scores for off-site hydrological and geomorphological impacts resulting from a variety of upstream/up-current/ downstream/down-current structures and human activities.

Table 6.4: Provisional scoring protocols for the magnitude-of-impact for different types of in-situ hydrological and geomorphological changes to naturalness

Provisional score	**Indicative types of hydrological +/or geomorphological change in naturalness**	**Commentary**
0	1. Little or no human mediated change 2. Reversal of past drainage resulting in similar overall pre-disturbance hydrological regime	1 Beach litter is addressed as a Tier-2 parameter 2 Campbell (2010) addresses hydrological restoration for wetlands
0.1-0.19	3. Average cutting height <2m; 4. Beach grooming with machinery 5. Average depth of fill <1m.	3 & 5 These are provisional and apply only to the area directly affected. Cuts and fills apply to different parts of a unit 4 For some beach certification awards (e.g. Blue Flag) beach grooming is seen to improve beach quality even though natural character is reduced (Cagilaba & Rennie 2005)
0.2-0.29	6. Average cutting height 2m -5m; 7. Average depth of fill 1-3m; 8. Drainage of a “wet area” 9. Conversion of a “wet area” to a shallow pond 10. Marine dredging &dumping sites.	6 & 7 These are provisional and apply only to the area directly affected 8 This applies to an already modified area 10 Ecological impacts are addressed separately
0.3-0.49	11. Average cutting height 5.1m- 8m high; 12. Lowering of dune crest by up to 5m; 13. Lower-reach river channelization and stop-banking alteration of base and flood flows; 14. Soft sediment marine dredging; 15. Change in permeability of sealed areas impacting downstream hydrology. 16. Prolonged lowering of wetland water table	11 &12These are provisional and apply only to the area directly affected 15 Allibone(2001) found that as the proportion of the catchment in impervious surfaces increased the EPT index (relative no. Emphemeroptera, Plecoptera and Trichoptera larvae) in urban streams declined. This effect was most pronounced as catchments moved from zero to 30% impervious surfaces

Provisional score	Indicative types of hydrological +/or geomorphological change in naturalness	Commentary
		16. Mid-point of a six-point parameter in Clarkson et al. (2004)
0.5-0.69	17. Large scale cuttings and fill with average cutting height 8m-15m 18. Removal floodplain functionality 19. Training walls at river mouths; 20. Sea walls 21. Groynes on a high energy coast 22. Medium sized dune “re-contouring” including removal of swales; 23. Replacement of natural stream banks with artificial structures, gabion baskets and other protection works.	18.Included in Reid et al. (2008) assessment of urban stream geomorphic condition 19 & 20 These are provisional and apply only to the area directly affected
0.7.-0.89	24. Large scale cuttings and fill with average cutting height 8m-15m 25. Tall dune re-contouring including removal of swales, 26. Sand mining; 27. Damming a waterbody to form an impoundment; 28. Drainage of a wetland system	28. The presence of man-made structures affecting the wetland and lowering of water table are two parameters in the New Zealand wetland condition monitoring programme (Clarkson et al. 2004). Drainage of the wetland system is a major impact but may be reversible if drain management is changed
0.9-0.99	29. Infilling or drainage of a lake; 30. Active landfill face; 31. Quarry; 32. Reclamation (of seabed); 33. Creation of (saltwater) canal system in dry land	29-33 These activities completely remove the former natural geomorphology and hydrological regime in the area directly affected

Table 6.5: Provisional scoring protocols for the magnitude of impact for different types of off-site hydrological and geomorphological changes to naturalness

Off site impacts	**Provisional score range**			
	0.05-0.1	0.11-0.2	0.21-0.3	0.31-0.4
Altered sediment & altered currents caused by a causeway or similar structure	Small-medium causeway, culvert of sufficient size to allow good water movement	Small-medium causeway, culvert too small so poor water flow Large causeway culvert of sufficient size for good water movement	Large causeway with culverts too small so poor water flow	Large causeway where water movement nearly blocked
Accelerated (estuarine) sedimentation associated with a river that has a modified catchment	Minor increase in sedimentation	Sedimentation >2 <10 times natural rates	Sedimentation >10 times natural rates	
Accelerated sedimentation from groynes along marine shorelines	Low level compared to natural rates	Moderate level compared to natural rates	Rapid rate compared to natural rates	
Displaced erosion (off-shore or down current caused by a seawall	Low level scattered local erosion compared to natural rates	Moderate level local erosion resulting from seawall compared to natural states	Major level local erosion resulting from seawall compared to natural states	Major widespread erosion resulting from seawalls compared to natural states

Section 5.5.2 contains the formula that combines the two hydrological and geomorphological naturalness parameters to give the Hydrological and Geomorphological Impact Score (HGIS). As the HGIS is subtracted from 1 to give the Hydrological and Geomorphological Naturalness Index (HGNI), the HGIS should not exceed 0.999 as this will lead to mathematical anomalies in the overall natural character index (NCI) formula. The calculation sheet provides a default score of 0.999 where the HGIS would otherwise exceed 0.999.

6.3.4 Parameters addressing building and structure heights

Height assessments complement the percent cover parameters to give an assessment of overall space or volume occupied by buildings and structures. The volume or space occupied can be moderated to some degree in the Buildings and Structures Impact Score (BSIS) by scores for colour naturalness and reflectivity.

The assessments of height are converted into height scores between 0 and 1for the BSIS formula. Earlier trials used a linear relationship between the assessed height and score (category). This had the effect of assigning a low impact to buildings relative to their spatial extent (in the BSIS formula) unless they were multi-storey buildings. After testing (chapters 2 and 9), a log-growth curve was selected as the most appropriate relationship between height in metres on the X axis and the height score between 0 and 1 on the Y axis (Figure 6.1).

Earlier trials used median height but again this was found to result in a lower score in locations where there were buildings of different heights. Maximum heights are now used. From a human perception perspective, a change in maximum height is likely to have a greater impact on natural character perception than the median height.

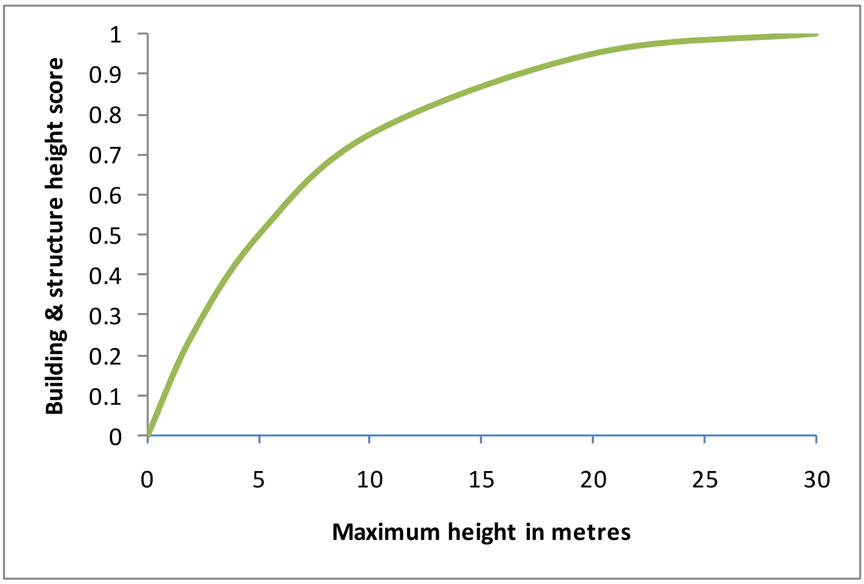


Figure 6.1: Relationship between building or structure height score and the maximum building or structure height

The assessments of building and structure heights are typically determined in the field by observation unless other information is available. In broad scale assessments it may be appropriate to use default scores for different circumstances related to maximum height limits permitted in district plans. Care will be needed to identify major outliers above the maximum height permitted in the plan but approved by way of a resource consent (e.g. the tall apartment building within an area of low stature buildings at Orewa Beach), and those that remain from earlier plan provisions. Conversely in some areas no buildings may reach the maximum allowed.

At 30metres and above the height score is 1. This has been selected as the cut-off point in recognition of the substantial impact of a building that reaches 30metres. It is recognised that context does affect the impact. A new 30m building would have less effect on the height score for a mapped unit where the surrounding buildings are 25m tall, compared to a location where other buildings are only 5m tall. Table 6.6 uses Figure 6.1 to construct a scoring regime for field use.

The height score for buildings and structures is the only core parameter not used in the *Viewpoint Methodology* (section 6.6.1). This is because the oblique perspective used in that methodology makes a height parameter unnecessary. Instead the effect of height is incorporated into the percent cover assessments.

Table 6.6: Scoring system for building and structure height

Score for BSIS formula	Height
0.25	2m
0.42	4m
0.5	5m
0.65	8m
0.75	10m
0.79	12m
0.95	20m
1.0	30m+

6.3.5 Parameters addressing building and structure colour "naturalness" and reflectivity

Scores for colour naturalness and reflectivity are used in the BSIS to moderate to a limited degree the effect of scores relating to the space occupied by buildings and structures. The colour naturalness and reflectivity parameters are included because a more “natural” colour and low reflectivity can help mitigate some adverse visual effects of buildings and structures. Because of this potential for mitigation, council planning documents may restrict building colours and/or reflectivity in environmentally sensitive locations. For example the proposed Hauraki Gulf Islands Section of the Auckland City District Plan (Auckland City Council 2006) seeks to minimise impacts of buildings in the landscape by specifying standards for exterior building colour. These standards are based on British Standard 5252 which classifies colours by hue, reflectivity and greyness.

The naturalness of the colours used on buildings and structures depends on the environmental context of those buildings and structures. Where buildings and structures are close to native forest olive greens, certain grey and brown tones most closely approximate nature's colours. Where buildings are close to dunes with a native sand-binder and low native scrub cover light greys or browns and yellow greens may be a closer match.

The overall colour naturalness of buildings and structures within a unit is assessed visually as being high, medium or low. "High", "medium" and "low" are not defined because they are context dependent. The scores used in the BSIS formula are in Table 6.7. Where there are many buildings or structures it is the overall "average" colour that is assessed.

The approximate light reflectance value (LRV) of a colour indicates the amount of visible light that a colour reflects. At one end of the range is black, with a light reflectance of 0% and at the other end is white which has a light reflectance of 100% (http://www.resene.co.nz/swatches/reflectance.htm). Colours with high reflectivity typically contrast with vegetation, especially native forests. Some people have avoided the use of darker colours because they absorb heat which can affect the stability of some building products and can increase the heat inside buildings in summer. A new technology, which reflects much of the infrared spectrum, allows darker colours to be used with a substantial reduction in the temperature of the surface of the building or structure (http://www.resene.co.nz/pdf/Reflectance_Curves.pdf).

Light reflectance values of different colours were obtained from the Resene Paints website (http://www.resene.co.nz/swatches/reflectance.htm). This is because New Zealand professional painters frequently use Resene paints and the Resene colours match pre-painted products such long-run and corrugate-profile roofing materials. Also, Resene Paints have developed palettes to address reflectivity and other colour requirements in some district plans (http://www.resene.co.nz/homeown/use_colr/usecolor.htm).

Although paint charts provide a reflectivity "score" for a particular tone, a typical building or group of buildings may incorporate many tones. Accordingly building and structure reflectivity is assessed visually in three categories-high, medium and low (Table 6.7). Where there are many buildings or structures it is the average reflectivity that is assessed. It was the difficulty of determining reflectance for many structures and buildings or even the variation within a single large structure that led to the use of a three category scale.

Table 6.7: Building and structure colour "naturalness" and reflectivity categories and associated scoring protocols

Building colour "naturalness" category	Scoring for BSIS formula	Building reflectivity category	Scoring for BSIS formula
High	0.8	Low	0.8
Medium	0.9	Medium	0.9
Low	1.0	High	1.0

6.3.6 Parameters addressing building and structure impacts in the marine environment

The terrestrial protocols are used for heights, colour naturalness and reflectivity of buildings and structures in the intertidal environment and for those on or above the (subtidal) water surface (e.g. houseboats). In the marine subtidal environment volume is used rather than height. It is based on the percentage of the water column a structure occupies. The scoring protocols for this are based on those used for heights.

In marine subtidal environments structures tend to be quickly covered by encrusting organisms except where this is activity prevented by anti-fouling coatings. Because of this, the colour naturalness and reflectivity parameters are of little relevance, except perhaps initially or where antifoul coatings are actively maintained. In the subtidal environment a major direct impact of structures (excluding hydrological and geomorphological effects which are addressed separately) is that they provide a new surface for encrusting organisms.

In many sheltered waters and some open coast environments, a new surface is often colonised by introduced species. This is most likely in areas where there are nearby, even temporary, sources of propagules from existing structures, boat traffic and the movement of aquaculture equipment. In these areas increases in structures provide more surfaces for the introduced species to colonise. These introduced species are often pest species (e.g. the alga *Undaria*). The new surfaces can also provide a site from which introduced species can colonise natural areas if there is a disturbance event like a major storm or canopy dieback due to natural causes, as can happen periodically with the indigenous tall brown alga *Ecklonia radiata*.

The parameter that is measured is the score representing the percent cover of the structure's surface that is covered by introduced benthic species. This is measured in categories because estimating percentage cover on an underwater structure is difficult as it is usually only possible to see part of a structure at a particular time. To retain some comparability with the equivalent terrestrial parameters it would be appropriate to use a partial scoring range. Further testing is recommended to determine an appropriate scoring system for this parameter. While the potential impact of alien species is greater than that of structure colour naturalness or reflectivity (equivalent terrestrial parameters in the BSIS), native and pest benthic cover more generally are addressed as *Tier-Two* parameters (section 6.5.1).

6.4 Terrestrial Tier-Two parameters

These parameters require higher resolution methodology than that used for the core parameters. They do not contribute to any of the three natural character indices that are combined into the overall natural character index for a unit. There are however opportunities to develop further sub-indices such as a naturalness of sound and light regime index.

6.4.1 Parameters addressing percent cover for native species and alien pest species

Parameters addressing percent cover for native species and alien pest species were initially proposed as part of the core indicator set. They were reassigned as *Tier-Two* parameters because their inclusion along with the parameter "*Score for progress towards present-potential cover*" in the Ecological Naturalness Index (ENI) resulted in double counting within that index in some circumstances.

While it is usually possible to estimate the percentage of native species in the canopy for forest and mature scrub using remotely sensed images and limited field checking, this is often not possible for lower stature vegetation and aquatic benthic cover. More detailed field inspection is typically required to assess percent cover for native and alien pest species in lower stature terrestrial vegetation. Depending on the level of accuracy required, it may be appropriate to use quick quantitative measures (e.g. point- height intercept (Handford 2000).

For more detailed assessments in multi-tiered terrestrial vegetation (primarily forest) the percent cover for both native species and alien pest species can be measured by tier. This is because levels of native and alien pest plants may vary between tiers. Quick quantitative methods (e.g. cylinder intercept method in Handford (2000) as modified by Froude (2008) for riparian vegetation) may be required to assess the percentage of native and pest-plant species by tier. For lakes, the LakeSPI methodology can be used to measure the relative cover of native and alien species.

To ensure consistency between measurement periods it is proposed that pest-plant species be those defined by the Department of Conservation as invasive weeds (Owen 1998; Froude 2002a). This is preferred over lists in regional pest management strategies. These lists are not complete because many widespread pest plants are omitted because of difficulties associated with requiring widespread species to be controlled in some way. The Department of Conservation pest plant lists are periodically updated which is appropriate given that it is the total pest-plant cover that is measured.

6.4.2 The naturalness of sounds

Two parameters address the naturalness of sounds:

- The risk of non-natural sounds
- The resilience of the "site" to non-natural sounds

Non-natural sounds are those from human sources including people, machinery and other human constructions and activities. Both risk and resilience are measured in categories: very low, low, low-moderate, moderate, moderate-high, high and very high. These two parameters address human perception of sound. Other biota can hear sounds at frequencies outside the range that may be detectable by humans.

Although these parameters are relatively easy to assess they can be very site specific. For example, moving a short distance behind a ridge crest may lead to a very different risk or resilience profile within the same mapped unit. Accordingly it is suggested that these parameters be applied at more detailed scales and when the *Viewpoint* or *Shoreline* methodologies are used.

The focus onnon-natural sound risk and resilience can provide a consistent assessment for a site and it removes the requirement for multiple site visits to measure sound levels at different times. Sound levels are traditionally measured using a logarithmic scale where an increase in 10 decibels (dB) means a sound is ten times as loud. All contributions to sound, whatever their source, are included. Sound levels can vary considerably depending on environmental features that block and amplify sound. Accordingly an accurate assessment of sound levels for a mapped unit would be a complex exercise. It would be further complicated by temporal variability in sounds.

In addition, because the standard decibel assessment measures all sounds it does not distinguish between sounds from "natural" and "unnatural" sources. This is of particular concern because sounds from "natural" sources (e.g. waves breaking on a shore) can act like white noise (http://science.howstuffworks.com.question47.htm accessed 20 July 2009), masking some unnatural sounds. To the average observer the overall pattern of sounds would seem more natural even though the actual level of sound (recorded in decibels) may be greater.

Where natural sounds mask unnatural sounds to some degree, this gives a site or a unit some level of "resilience" to unnatural sounds. The day to day resilience of a site can vary. Accordingly an assessment is made of the likely "typical" resilience based on exposure to wind and waves, the shore type and local topography. For example an enclosed arm of a harbour surrounded by hills would show low resilience because the enclosing topography acts like an amphitheatre. In contrast, an exposed open coast escarpment or beach subject to frequent surf/ breaking waves and strong winds would show high resilience. Wind and wave height data may assist an assessor to determine resilience to non-natural sounds, where that assessor has a low level of familiarity with an area.

Factors affecting the risk of non-natural sounds include: the proximity of road, rail, sea and air transport routes and facilities (including ports and construction/maintenance sites); the level of use of those routes/facilities; the proximity and types of settlement; the proximity and types of commercial and industrial activities; the proximity and levels of recreational activities that create non-natural sounds (e.g. water skiing), and the proximity of different types of agricultural activities and grounds maintenance activities (including lawn mowing and chain-saw use). Coastal areas with a low level of risk of unnatural sounds are typically remote with difficult access (because of distance and/or conditions) for mechanised transport and no human settlement or industrial/agricultural activities. Coastal areas with the highest risks of unnatural sounds include those at or adjoining busy airports, sea ports and major roads. Various industrial, recreational and agricultural activities can also result in a high risk of non-natural sounds for some coastal areas, although there can be more temporal and/or seasonal variation.

Sound risk and resilience assessments address typical daytime risk and resilience. On any one day the risk and/or resilience at a site may differ from the typical. For example, there may be no wind or surf sounds at an exposed site with typically moderate to high resilience. Conversely non-natural sounds may be atypically high because some large trees are being felled using chainsaws in an area that typically has few mechanised sounds.

6.4.3 Anthropogenic light

Anthropogenic light affects plants and animals as well as human perceptions of naturalness. The parameter, *level of risk of anthropogenic light*, is assessed in categories (nil, low, low-medium, medium, medium-high, high, very high). It is based on an assessment of likely anthropogenic light sources and their relative strength. As with the parameters addressing sound risk and resilience, this parameter is relatively easy to measure, but can be very site specific. It is suggested that the anthropogenic light parameter be applied at more detailed scales and when the *Viewpoint* and *Shoreline* methodologies are used

Ideally the risk of anthropogenic light would be assessed at night. As this is not usually practical, this parameter can be assessed in daylight hours provided that there is a thorough assessment of likely anthropogenic light sources that could affect the site. For example, many small Northland coastal settlements have no street lighting and so the resultant anthropogenic light levels are relatively low.

The types of coastal areas at risk of high levels of anthropogenic light include those within line of sight of moderate to large human settlements, commercial areas and major transport facilities (including motorways and ports); those near isolated facilities that use high levels of lighting (e.g. major traffic intersections, outdoor night-time sports and entertainment facilities); and those near sites requiring high levels of night-time security lighting. Areas near, but not necessarily within direct line of sight of, major urban areas typically see a reduction in background darkness levels irrespective of local sources of anthropogenic light.

Remotecoastal areas with little, or preferably no, human settlement and/or are off common travel routes have a low risk of anthropogenic light. Open ocean sites away from settlements, common shipping routes and industrial-scale fishing have a very low risk of anthropogenic light.

6.4.4 Indicator species

Indicator species are those where changes in their distribution, abundance and condition represent wider scale changes in the environment. The measurement of mobile indicator species (*Status of indicator species that represent the state of naturalness)* requires repeat measurements using appropriate protocols to address seasonal migrations (e.g. snapper, rock lobster) and seasonal variability in how visible they are to observers primarily because of behaviour changes (e.g. dotterel, kingfisher). Replicate sets of quantitative data are needed for abundance estimates unless populations are so low and their visibility is sufficiently high that it is possible to undertake a census.

For terrestrial environments the primary parameter addressing indicator species is the *abundance and condition of pohutukawa, especially on rocky coasts*. Pohutukawa is selected as an indicator species because it: is an iconic species for northern New Zealand; approximately 90% of the original area of pohutukawa has been lost (Hosking et al. 1989); in 1989 an assessment showed the pohutukawa in Northland were in poorest condition (relative to other areas) and that many old trees had recently died(Hosking et al. 1989); is at risk from a wide variety of factors including clearance, humans causing root and stem damage, fire and possum defoliation(Hosking et al. 1989); is a beneficiary of possum control programmes as part of TB vector control, Department of Conservation and community control programmes; and is subject to a national restoration programme, Project Crimson. A 2000 assessment (Hosking 2000) of pohutukawa found that there had been a significant decline in possum damage and a large increase in regeneration. Much of this was attributed to a comprehensive suite of actions including possum eradication and control programmes, fencing and restoration planting.

Mature healthy pohutukawa along rocky (and other) coastal margins is an indicator of coastline naturalness in northern New Zealand. Pohutukawa parameters assessed in the field are:

- % length rocky coast (and other coastal type) with pohutukawa
- % length rocky coast with mature pohutukawa
- Condition class for mature pohutukawa as measured using the foliar browse scale (<5%. 5-25%, 25-50%, 51-75%, >75%) (Payton et al. 1999) with an added category of dead

Mature pohutukawa are defined as those >8m tall, although trees 4-8m high in highly exposed sites where the branch spread is greater than the tree height are also classified as mature for the purposes of this parameter.

Iconic species typically have special value beyond their contribution to natural character. To date it has not been possible to develop a way to integrate the iconic species data with other unit parameter data and avoid double-counting. Until this matter is resolved it is proposed that this data be reported separately, and only for more detailed assessments.

6.5 Marine Tier Two parameters

6.5.1 Parameters addressing percent-cover for native and alien pest species

Percent-cover parameters for native species and alien pest species were initially proposed as part of the core parameter set for marine environments. This option was later rejected because of the risk of double-counting within the ENI index.

Before the % native cover can be estimated it is necessary to distinguish between native and introduced species. This can be difficult in some marine environments without a good knowledge of different benthic species. Cranfield et al. (1998) identified 148 species that had been introduced into New Zealand marine waters accidentally as well as four deliberately introduced species. They found that repeated introductions, enclosed receiving waters and certain characteristics of the species were important factors in the establishment of introduced marine species. A recent survey found 13 introduced species in waters around the Opua Port (National Institute of Water and Atmospheric Research 2009). This is less than what is found in major ports such as Auckland.

Recognition of the potential risks of alien species in the marine environment probably happened later than for terrestrial and freshwater environments. The first compilation of adventive species for the New Zealand marine environment was by Cranfield et al (1998). This report did not identify which of these species were pests. Various marine alien species have been identified by Biosecurity New Zealand (2009) as pest species for the purposes of surveillance and containment. This list is not comprehensiveand there are other species not on this list (e.g. Pacific oyster (*Crassostrea gigas*)) that have adversely affected natural character.

Given the species indication problems in some environments, it is suggested that the initial focus be on known introduced species that have an adverse effect on naturalness. One such species is the intertidal Pacific oyster. Further work is required to assemble a list of appropriate species for different parts of New Zealand. Given the difficulty of estimating percent cover in subtidal environments it may be most appropriate to use cover classes (section 5.4.3).

Harbours, estuaries and other sheltered waters are the most likely marine environments to contain alien benthic species. The risk is highest for those waterways where: vessels are stationary at a berth or at anchor; equipment such as that used by marine farms and infrastructure projects is moved between waterways; and new surfaces such as wharves and jetties are provided. As the major areas that are at risk from alien species tend to be in the vicinity of ports, harbours and other sheltered waters, more effort should be made to estimate likely cover by alien species in these areas. This is likely to be difficult where low water clarity makes it difficult to estimate cover. In such situations estimates are likely to be indicative.

6.5.2 Parameters that address long term water clarity changes in marine environments

Plants can be useful indicators of long term trends in water clarity. This is because they integrate a range of environmental conditions supporting plant growth over an extended period of time prior to sampling (Clayton et al. 2002). This contrasts with physical and chemical assessments (e.g. Secchi disc transparency) which measure factors that can change frequently and so need frequent measurements to identify long term trends.

In Europe the lower depth limits of members of the tall brown algae order Laminariales were found to vary by more than an order of magnitude because of water clarity (Luning 1991). The limits were similar if they were expressed as light percentage depth. The New Zealand members of the Laminariales include species in the *Lessonia*, *Ecklonia* and *Macrocystis* genera. *Ecklonia radiata* is the primary tall brown algal species that forms the lower depth limit for brown algae species on the open coast of northern New Zealand.

Individual algal plants can be found at depths of at least 60m in the clearer waters of offshore islands (Choat & Schiel 1982). As this depth is too great for regular scientific diving, it is proposed that the parameter *maximum depth of continuous tall brown algal forest* be used to measure long-term changes in water clarity where there is rocky substrate. For the purposes of this parameter, the maximum depth of continuous tall brown algal forest is where algal cover is greater or equal to 75%. This minimises the depths to be dived and so improves safety. Maximum depths would need to be measured in several locations within a unit to ensure that an average maximum depth limit is identified.

As *Ecklonia* requires suitable substrate for the holdfast to attach to, care will be needed to ensure the observed maximum depths are limited by water clarity and not substrate. This would be particularly important if the focus was on the maximum depth of any *Ecklonia* plants. Novaczek (1984) found the depth distribution of *Ecklonia* sporophytes at Goat Island Bay was substrate-limited at 22 metres.

Where there is solid or broken rock substrate in sheltered waters with lower water clarity the New Zealand tall brown algae species reaching the deepest depths are often members of the genus *Carpophyllum* from the order Fucales. These depths are less than what occurs on the open coast, and in turbid waters may be only a couple of metres.

The absence of submerged seagrass beds from most New Zealand harbours is probably because of poor water clarity reducing light levels (Inglis 2003). It is likely that existence of permanently submerged seagrass beds on sheltered soft sediments adjoining some offshore islands is because of the relatively high water clarity in those locations (Schwarz et al. 2006). It is proposed that the parameter *changes in the extent of subtidal (permanently submerged) seagrass beds* be used to assess long-term trends in water clarity for shallow subtidal soft-sediment marine environments.

6.5.3 Parameters that use indicator species

Section 6.4.4 discussed the use of indicator species for terrestrial coastal environments. The same parameter *Status of indicator species that represent the state of naturalness* is used for marine environments.

Parameters proposed for near shore soft sediment environments are:

- Subtidal sea grass extent and density (this is also an indicator of water clarity in sheltered shallow subtidal environments)
- Horse mussel (*Atrina zelandica*) extent and abundance
- Snapper (*Pagrus auratus*) relative abundance

Subtidal seagrass is adversely affected by poor water clarity (Inglis 2003), sedimentation and disturbance such as anchoring. It is thought that it was once much more widespread in harbours (Inglis 2003). Recently, some northern offshore subtidal seagrass beds have been shown to have higher macroinvertebrate abundance and diversity than intertidal mainland sites and high fish populations, especially juvenile snapper (Schwarz et al. 2006). Subtidal sea grass extent can be monitored by measuring changes in the extent of patches.

Horse mussels are readily damaged by dredging (the predominant commercial method for harvesting scallops that is also used by recreational fishers), anchoring and trawling. Intact beds of horse mussels in shallow soft sediment subtidal environments indicate a relatively undisturbed benthic environment. Such beds are likely to be much less common today because of the widespread disturbances of shallow soft sediment seabed (Thrush & Dayton 2002). While changes in extent can be measured, more work is required to construct a suitable baseline.

Indicator speciesparameters proposed for near shore hard substrate environments are:

- Presence and relative abundance of snapper (*Pagrus auratus*), butterfish (*Odax pullus*), rock lobster (*Jasus edwardsii*) and blue cod (*Parapercis colias*)

- Presence and relative abundance of the New Zealand sea urchin or kina (*Evechinus chloroticus*)

The distribution and relative abundance of the species in the first hard-substrate parameter reflects the level of direct harvest pressure on those species. Changes in abundance of species that predate kina (snapper and rock lobster) can have a major impact on the wider marine ecosystem.

Shears & Babcock (2003) describe benthic community changes at Leigh Marine Reserve since the reserve's establishment in 1978. The benthic community has changed from being one dominated by kina to one dominated by macro-algae. This change was considered to be the result of a trophic cascade that was an indirect effect of increased numbers of predators of kina. The dramatically increased numbers of predators, especially rock lobster and snapper, are an outcome of the no-fishing rule in the Leigh Marine Reserve (Willis et al. 2003; Shears et al. 2006).

The relative abundance of various reef fish species is typically measured using diver surveys with belt transects as described by Taylor et al (2005) although they preferred the use of baited underwater video to assess the abundance of snapper. It is proposed that the relative abundance of snapper, butterfish, rock lobster and blue cod be assessed using standard methods and compared with an appropriate marine reserve baseline. A further step could be to convert the relative abundance data into a format that would be suitable for constructing an index, thereby facilitating comparisons between locations.

It is proposed thatthe relative abundance of kina be assessed using standard methods (with belt transects or quadrats). Interpreation of this parameter is potentially more complex as kina abundance is affected by both direct harvest and by the removal of its predators. As previously described, predation on kina that occurs in long-term no-take marine reserves can led to a dramatic recovery in shallow benthic communities from one dominated by kina to one dominated by macro-algae.

In northern areas without reserves, kina is a key species determining the ecology of shallow subtidal reefs (Andrew 1988). It directly affects the distribution and abundance of tall brown algae species in shallow waters as well as a range of herbivores. Relative abundance of kina can be estimated (by size class) using either belt transects or quadrats. It may also be useful to estimate the upper depth of *Ecklonia* forest (as well as the bottom depth as a measure of water clarity). The inside and outside marine reserve comparisons found the greatest differences in algal communities were at depths where kina were most abundant (4-6m) (Shears & Babcock 2003). Leigh Marine Reserve provides baseline abundance data for kina in north-eastern New Zealand.

6.5.4 Parameters that address sound and light

The sound and light parameters used for the marine environment are the same as those are used for the terrestrial environment. That is, the parameters address risk and resilience.

The assessment of the risk of and resilience to unnatural sounds on the water surface is the same as for the terrestrial coastal environments. Underwater sound affects marine biota as well as humans who venture underwater. Sounds affect a variety of fish behaviours including migration and habitat selection and probably assist pre-settlement reef fish to find “their” reef. Sound is also a component of marine mammal behaviour including migration/navigation, feeding and communication. Human generated sounds can affect these processes as well as humans visiting the subtidal. The primary sources of non-natural sounds heard underwater are motorised craft of all types and underwater construction activities (e.g. piling).

The light impact on subtidal environments is primarily associated with facilities such as ports, marinas and wharves and heavily developed shores. In the context of the subtidal marine environment these impacts are relatively localised. Temporary impacts are associated with night fishing.

6.6 Perspectives for assessing natural character

The standard QINCCE methodology assesses parameters in plan-view mapped units as described in Chapter 5. Two additional perspectives are available for more detailed assessments.

6.6.1 Viewpoint assessment

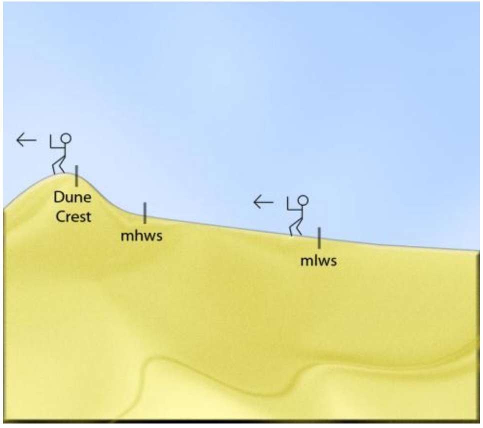
The oblique *Viewpoint* uses a grid that can be held or supported on a pole or placed over an image on a computer screen. Where a *Viewpoint* is directly assessed in the field, a fixed-dimension frame with a 5x4 grid is held at a set distance from the body to provide a quantitative way to assess the relative composition of the "view". The size and position of the grid are designed to "match" the angle of view of an observer.

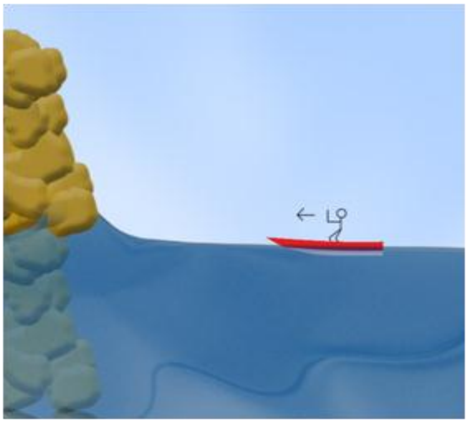
The viewpoint position is always on public land or the sea and the direction of view is typically at right angles to the shore. Common viewpoints are the near shore looking onshore (usually from a boat), at low or mid-tide looking onshore, on the crest of the foredune, or at a public view point looking either onshore or offshore. Figure 6.2 provides examples of viewpoint positions.

The purpose of the grid is to assist estimates of percent cover. Where there is undulating or hilly topography the top line of the grid should be lined up with the crest of the highest point. Where the topography is flat the top of the second line of the grid should be lined up with the highest point.

The *Viewpoint* methodology uses all the core parameters apart from building and structure height. In addition the parameters addressing sound naturalness and anthropogenic light are also assessed at the *Viewpoint* origins. *Viewpoints* can be set up at particular places of interest or they can be established on a systematic or random basis. Establishing *viewpoints* on a systematic basis will facilitate a greater degree of extrapolation from a limited number of sample points.

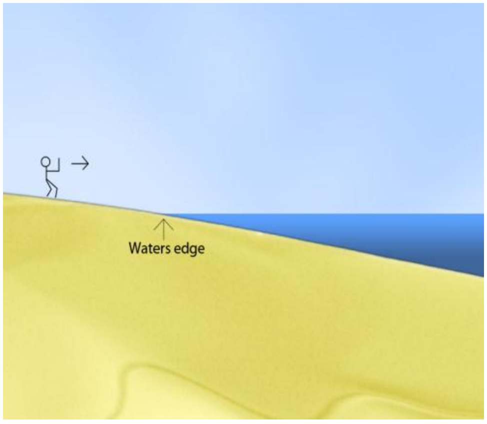
It is important that the *viewpoint* date and time is recorded along with the nearest high tide. The stage in the tidal cycle can significantly alter some percent cover assessments in some locations. It may be necessary to make adjustments at the time of analysis to take account of the tidal stage at the time of the assessments.

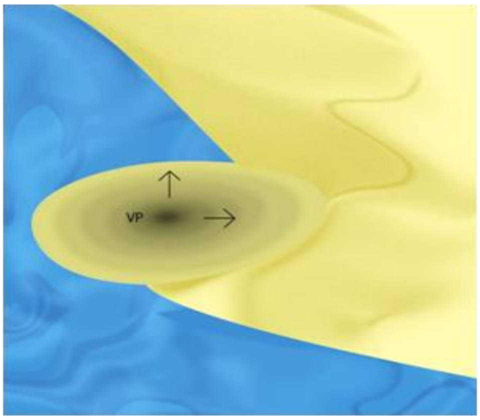




1. Towards inshore from
   - foredune crest
   - mean low water springs

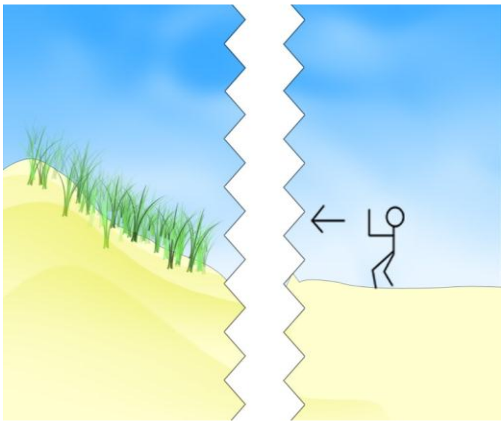
2. To rocky coast from a boat





3. From land to sea

4. From public coastal land to inshore



5. From land on the coast looking inland

Figure 6.2: Viewpoint assessment positions in different types of coastal environment

6.6.2 Measuring the natural character of the "shoreline"

The "shoreline" is a narrow width of coast straddling mean high water springs. As it is the land-water interface it can be subject to a variety of pressures that are not typical of the terrestrial or aquatic units that it may be part of. In addition this area is often one of great interest and focus in human assessments of natural character.

Typically the "shoreline" is too narrow to map as a separate unit except for very detailed assessments. The core parameters would be measured over a narrow band -the exact width would depend on the specific stretch of coast and would need to be clearly specified. It may also be useful to also address relevant *Tier-Two* parameters such as: percent native cover; and presence of certain indicator species representing naturalness. Shoreline specific parameters that could be used in more detailed assessments include: the abundance of litter; the relative positions of structures; and the amount and impacts of vehicle use.

6.7 Conclusion

Core and *Tier-Two* parameters are based on different levels of theoretical and practical underpinning. The ecological parameters (Chapters 6 and 7) are most thoroughly developed and supported by research. There is less available research and empirical data to provide a strong theoretical underpinning for the provisional scoring protocols for the hydrological and geomorphological naturalness parameters. The parameters addressing building and structure impacts primarily focus on bulk or space occupied, with this adjusted by colour naturalness and reflectivity for terrestrial and intertidal environments and the water surface. In subtidal environments the coverage of structures by alien species is assessed instead of colour naturalness and reflectivity.

The *Tier-Two* parameters are intended for detailed assessments only. At this stage it has not been possible to develop a methodology to combine scores from these parameters into an index or indices (except for a naturalness of sound and light index). The availability of different perspectives for natural character assessment provides opportunities for more detailed assessment where this required.

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7 QINCCE methodology: Comparing current state with present-potential natural state for cover, geomorphology and hydrology

Foreword

This chapter has been prepared as a stand-alone paper to be submitted to a journal after modifications have been made to address the requirements of the journal. Concept development was undertaken in Northland, New Zealand. The detail relating to this is addressed in Appendix 5.

Abstract

Several indicators in the Quantitative Index for measuring natural character (QINCCE) methodology use "reference conditions" against which natural character is assessed. Reference conditions used include *present-potential cover* for the indicator *progress towards present-potential cover*; and *present-potential natural state* for the indicator *hydrological and geomorphological naturalness.* The purposes of this paper are to develop the concepts of *present-potential cover* and *present-potential natural state* as generic categories of reference condition; and construct and trial a framework for assessing progress towards the reference condition *present-potential cover.*

This paper explores the impact of different types of disturbance (including natural, human-induced on-site, human-induced offsite) and introduced species on *present-potential cover* and the hydrological and geomorphological naturalness parameters with their reference condition of *present-potential natural state*. Protocols for addressing different types of disturbance are developed for the QINCCE parameters.

Processes for determining *present-potential cover* for coastal Northland, New Zealand are described. Methodology used to construct scoring tables used for the QINCCE parameter *Score for progress to present-potential cover* is justified. Provisional scoring tables are provided for the different coastal Northland situations where the *present-potential cover* is indigenous forest.

Keywords:
Baselines, disturbance, ecological naturalness, ecological restoration, hydrological and geomorphological naturalness, natural character, potential vegetation, present-potential cover, reference conditions, succession,

7.1 Introduction

The comprehensive definition of natural character in Froude et al. (2010) states that the level of natural character present at a site (at any scale) is the degree to which that site:

- *"is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous "biological artefacts"*
- *exhibits fidelity to the geomorphology, hydrology and biological structure, composition and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable with reference conditions "*

This definition uses "reference conditions" as the benchmark against which ecological, hydrological or geomorphological naturalness is assessed. Reference conditions (Higgs 2003) can provide for certain irreversible biological changes (e.g. species extinctions) as well as the consequential biological, hydrological and geomorphological changes resulting from irreversible events such as volcanic eruptions. In contrast, a time-bound "baseline" is like a "snapshot" of a particular time that does not address irreversible changes that have happened in the interim.

The parameters used for the QINCCE methodology contain implicit or explicit reference conditions (or baselines). For those parameters relating to cover – the implicit reference condition is a biological cover or natural surface where any biological cover is completely indigenous and the surface has not been altered from the natural state by human activities. The implied reference conditions for the parameters that contribute to the Buildings and Structures Impact Score (BSIS) is the complete absence of buildings, human structures and paved/surfaced areas.

There are three indicators for which the reference conditions are more complex:

- Progress to present-potential cover
- Hydrological and geomorphic naturalness
- Status of indicator species that represent the state of naturalness

This chapter reviews relevant literature before refining and extending the concept of potential vegetation into the generic reference condition *present-potential natural state*. It is this generic reference condition that is used in the evaluation of the parameters associated with the above three indicators. Protocols for scoring the impacts on *present-potential natural state* resulting from human-mediated changes tocoastal geomorphology, hydrology and hydraulics are developed. These address impacts from both on-site and off-site changes, and include impacts on *present-potential cover*. Protocols for scoring progress towards the *present-potential cover* of indigenous forest are developed.

Detailed information on *present-potential cover* and ecological succession data used to develop scoring protocols for assessing progress towards *present-potential cover* for different types of coastal environment in eastern Northland, New Zealand are in Appendix 5.

7.2 The concept of potential vegetation and its applications

The concept of potential vegetation has been applied to terrestrial vegetation at the broad scale (e.g. Leathwick et al. (2004); Capelo et al. (2007); Alo & Wang (2008)). Reasons for its use have included developing and applying an environment classification (Leathwick et al. 2003), developing ecological restoration strategies (Leathwick et al. 2003; Zhou et al. 2008; Zou et al. 2009), understanding the consequences of historical land use changes (Ramankutty & Foley 1999; Pongratz et al. 2008; Steyaert & Knox 2008) and evaluating the possible impacts of future climate change scenarios (Alo & Wang 2008; Dabang 2008; O'ishi & Abe-Ouchi 2009; Zou et al. 2009). Country-scale maps of potential vegetation have been prepared using GIS technology for New Zealand (Leathwick et al. 2004), China (Dabang 2008), Switzerland (Brzeziecki et al. 1993) and Portugal (Capelo et al. 2007). A map of potential vegetation of conterminous USA was prepared manually in the early 1960's (Kuchler 1964) and the eastern sector was later digitised (Steyaert and Knox 2008). Global scale low resolution maps of potential vegetation have been prepared by several authors (Ramankutty & Foley 1999; Alo & Wang 2008).

There does not appear to be a single interpretation of "potential vegetation". The most common interpretation is that it is the climax vegetation that would be expected at a site given its climatic regime and possibly other site-related factors. Kuchler (1964) defined potential natural vegetation as "*the vegetation that would exist today if Man were removed from the scene and if the resulting plant succession were telescoped into a single moment*". A more expansive definition was provided by Zou et al. (2009) (after Ren (2004)) as follows:

"…the growing natural vegetation, which is in an ultimate equilibrium succession process between vegetation and its niches without human interferences, characteristic of its adaptive vegetation evolution through changing environments, which is closely related to regional environmental conditions, especially climate changes. It is the most stable, most mature vegetation climax that a niche can develop into. Due to the disturbance of human activities and other factors, the vegetation in most areas on the earth cannot represent potential vegetation."

Potential vegetation is often linked to a time period, dependent on the purpose for constructing the pattern of potential vegetation. Investigations of the effect of climate change may compare potential vegetation of the past (e.g. pre-industrial (Alo & Wang 2008)) with potential vegetation of the future. Studies focusing on ecological restoration typically address the potential vegetation of the present (e.g. Zhou et al. (2008); Zou et al. (2009)). When potential vegetation patterns are being constructed assumptions need to be made about various physical parameters for the time period of interest. For example, Steyaert and Knox (2008) found that before they could construct an accurate potential vegetation map for a particular historical period they needed firstly to construct a saturated soils map for that time. If they had not done this the extent and distribution of potential wetland vegetation for this historical time would be inaccurate.

To date, potential vegetation or cover assessments have focussed on the terrestrial environment and have generally been at a broad scale. Constructions or simulations of potential vegetation have typically focused on climate variables. For example, in the Western Chinese Loess Plateau, Zhou et al. (2008) used weather data to determine vegetation climaxes (in the absence of remaining climax vegetation) by way of the Holdridge model (Yates et al. 2004). The Holdridge model focuses on the relationship between climate and vegetation, and uses weather data to determine vegetation climaxes that could be present in the absence of disturbance (Tosi 1964).

A more complex set of variables was used to construct broad-scale potential forest and potential vegetation maps in New Zealand. This approach also addressed discontinuous distributions in key habitat-forming *Nothofagus* tree species. Leathwick (2001) predicted New Zealand's potential forest composition using regressions relating the distributions of major tree species to a suite of environmental variables relating to climate and soils. This assessment required adjustment using species distribution data (Leathwick 2001) to address the disjunct distributions of the keystone *Nothofagus* species (beech). These disjunct distributions reflect New Zealand's history of glaciation, vulcanism and plate tectonics (McGlone et al. 1996) as well as beech's slow dispersal rates (Wardle 1984), and cannot be explained using environmental factors at the landscape scale (Leathwick 1998). Disturbances at a more local scale, such as damage caused by storms, landslides or earthquakes were not generally addressed by the 1km nation-wide modelling grid used by Leathwick (2001) to predict the potential forest pattern.

Leathwick's (2001) approach was extended to the development of a numerical automatic classification of New Zealand terrestrial environments using a set of 15 climate, landform and soil drivers that were selected because of their role as key environmental drivers affecting vegetation (especially forest) pattern (Leathwick et al. 2003). The four soil and landform variables were not given the same weighting in the model algorithms as the climate variables (Leathwick et al. 2002). Their inclusion in the model improved the accuracy of the resulting classification -Land Environments of New Zealand (LENZ). LENZ and the underlying data layers can be used to reconstruct potential forest composition and provide the context for determining potential vegetation. The LENZ focus on forest reflects the fact that forest was the predominant pre-human terrestrial vegetation in New Zealand (McGlone 1989).

7.3 Refining the present vegetation concept for use in the QINCCE methodology

The lack of consistency within the published literature in actual or implied definitions of "potential vegetation" can lead to ambiguity in some contexts. In the context of the QINCCE methodology it is present-day potential vegetation or cover that is of interest. For the avoidance of doubt this is described as *present-potential cover.* This is the vegetation/cover that would be expected today if humans, their tools and technology and introduced species they brought with them, had not arrived in New Zealand; but geological, climatic and other natural disturbances and physical changes had occurred.

Terrestrial *present-potential cover*differs from the pre-human cover in that it takes account of the natural environmental disturbances and changes that have occurred since human arrival in New Zealand approximately 730 years ago (Wilmshurst et al. 2008). These natural changes may be episodic and major (e.g. volcanic eruptions or tsunamis (McFadgen 2007)) or more regular and of lesser magnitude (e.g. alternating phases of coastal dune erosion and accretion in response to climatic cycles).

Present-potential cover for an area is not necessarily the so-called "climax" cover. In a frequently disturbed environment such as a river mouth on a soft-sediment coast, bare surfaces and cover adapted to frequent disturbance (e.g. native sand binders) would be the likely *present-potential cover*. Present-potential cover also takes account of the timing of disturbances. For example the present-potential cover for a recent landslide triggered by heavy rain would be early seral vegetation rather than mature indigenous forest (which may the present-potential cover for surrounding areas).

The application of the concept of present-potential cover in the QINCCE methodology is at a finer scale than is usually used for determining potential vegetation. It is therefore necessary to look beyond factors often considered in determining potential vegetation patterns.

In Franklin’s (1995) model climate, geology and topography were the underlying drivers of potential vegetation, with natural and anthropogenic disturbance interacting with potential vegetation to produce the observed vegetation as sensed by a remote sensing device. Figures 7.1 and 7.2 expand this model.

Figure 7.1 identifies key factors determining *present-potential vegetation* at broad and fine scales. In distinguishing between broad and fine scale present-potential vegetation it introduces factors affecting fine-scale potential vegetation including local hydrological patterns and local site conditions such as slope, aspect and groundwater salinity. This more complex picture of factors determining present-potential vegetation is necessary when applying the QINCCE parameter *Score representing progress towards present-potential* cover at detailed scales. In Figure 7.2 various anthropogenic influences or factors modify present-potential cover at a site to give the actual vegetation.

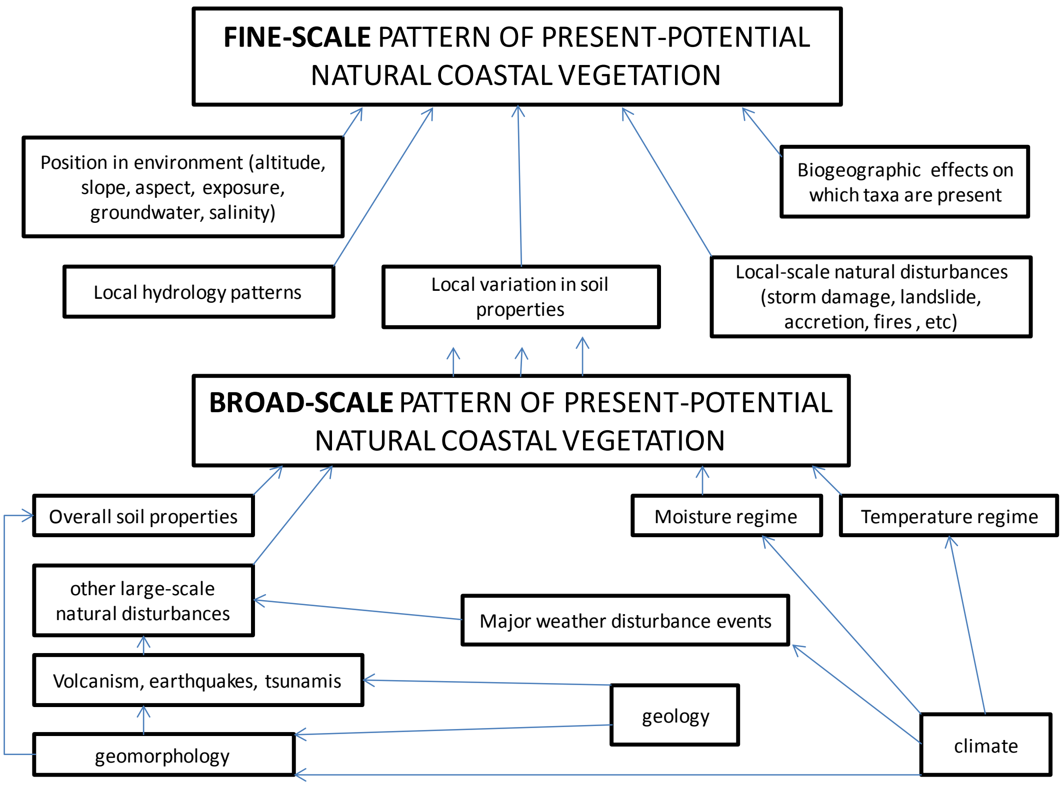

Figure 7.1: Factors determining present-potential cover at broad and fine scales

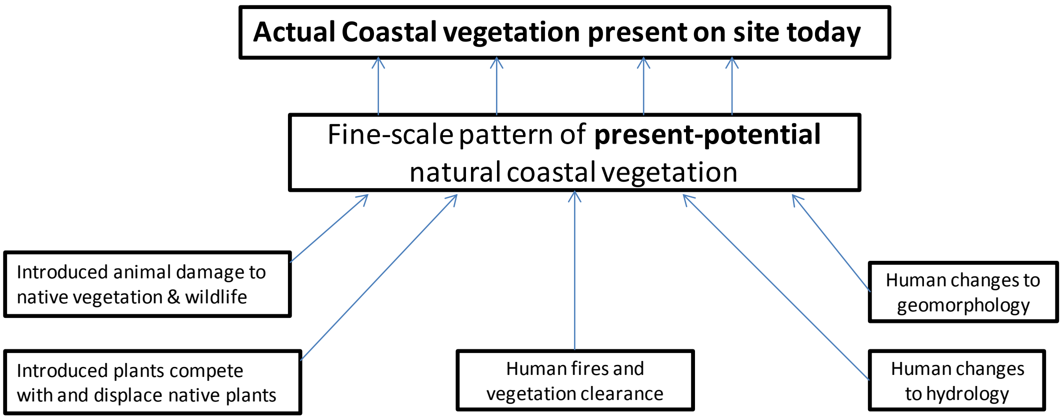

Figure 7.2: Anthropogenic factors that modifythe present-potential cover for a site to give the actual vegetation

The *present-potential cover* of New Zealand terrestrial coastal environment is a complex mosaic that is determined by the interaction of factors often acting at a more detailed scale than used in the compilation of the data sets underlying LENZ and constructions of potential vegetation for New Zealand. At the scale at which the QINCCE methodology is generally applied the terrestrial *present-potential cover* is a complex mosaic resulting from variations in: local hydrology, geomorphology and soil patterns; local site conditions (e.g. high levels of exposure to wind and salt); and natural disturbance events (e.g. coastal erosion and accretion cycles). The environments identified at the most detailed level of the LENZ classification (Level 4) were not sufficiently detailed to use as a basis for determining *present-potential vegetation* of the coastal environment for the QINCCE case studies. Instead, a variety of information sources was used to construct the *present-potential cover* for the eastern Northland case studies.

7.4 Extending the underlying concept of potential cover to other natural systems

The concept of potential cover does not seem to have been specifically extended to non-vegetated and aquatic environments. In marine environments this cover can be dominated by plants or anaimals. Encrusting fauna such as sponges, bryozoans, corals and molluscs can cover extensive areas. There are also extensive areas of soft sediment where there is little or no obvious biotic cover, although there may be abundant infauna (e.g. bivalves, marine worms) below the surface.

The QINCCE methodology uses the parameter *progress towards present-potential cover* in both the marine and terrestrial coastal environments. Determining *present-potential cover* for marine environments can be challenging because of a lack of information, particularly about historical states and historical human modifications.

A further extension is the concept of *present-potential natural state* for use with parameters on hydrological and geomorphological naturalness and the naturalness of mobile fauna distribution and abundance. *Present-potential natural state* is that which would be expected today had humans, their tools and technology and introduced species they brought with them, not arrived in New Zealand. It does not include species that are, or are thought to be, extinct. This is because it is impossible to reinstate extinct species. If extinct species o were included as part of the natural character reference condition would set the “100% natural bar” too high. It would not be possible to reach this “100% natural” state even if there were no constraints on resource availability to establish ideal conditions, and there was unlimited time over which changes to a more natural state could occur.

Past applications of *present-potential natural state* or similar concepts to hydrological, geomorphic or other physical parameters has been limited. One example is a historical potential saturated soils map for the eastern USA prepared by Steyaert and Knox (2008). Others may have used the concept without specifically using the term "potential" to apply to the characteristic of interest. In the context of British rivers Newson (2002) defined the (geomorphic) reference condition for rivers as "*possess[ing] the full range of plan-form, sectional geometry and features representing the full interplay of water and sediment fluxes within local boundary conditions. 'Natural' rivers are free to adjust their form and features*…." This could be similar to a summary description of *present-potential natural state* for river geomorphology and hydrology.

7.4.1 Measuring progress to present-potential cover in aquatic environments

It can be difficult to determine *present-potential cover* in marine environments because there:are uncertainties about the spatial extent of many marine environments and their associated ecological communities;is a lack of information about many marine ecological processes and the impact of these processes on the composition and structure of benthic cover; and there is an absence of large un-impacted marine environments to provide baseline information needed to determine *present-potential cover*. The profound long-term impacts of human harvest and land use activities on marine ecosystems had not been recognised until recently, thereby leading people to conclude areas were completely natural when they were not (Jackson 2001).

Constructions of *present-potential cover* for the marine environment use the same principles as for the terrestrial environment, although there are major differences in the availability of the necessary information. Key physical factors determining *present-potential cover* in the marine environment include depth (affects light, pressure and surge effects), substrate physical properties, sea temperature regime, oceanic currents (e.g. East Auckland Current), tidal currents, salinity regime, natural fertility of substrates and water, and natural disturbance regimes (e.g. storms). The key biological factors influencing *present-potential cover* are availability of propagules and interactions between natural consumers and the benthos. As on land, natural disturbance events can have major impact on the *present-potential cover* for some marine environments. Coastal lake *present-potential cover* is determined by a similar group of factors, with the addition of the natural lake-waters mixing regime, and minus ocean and tidal current effects.

One characteristic of some aquatic environments that complicates the assessment of *present-potential cover* is the often dramatic effects of what can be frequent natural disturbance. The frequency of disturbance for some shallow aquatic environments, especially on exposed coasts, can be high especially when compared to the return periods for major natural disturbances of terrestrial environments. The nearest equivalent in the terrestrial environment is the foredune on an eroding coast or an area of active (natural) river-mouth migration.

7.4.2 Present-potential natural state for geomorphology and hydrology

There have been many natural changes to hydrology and geomorphology since humans arrived in New Zealand. Examples of such changes that need to be incorporated into the hydrological and geomorphological present-potential natural state include:

- Seabed and coastal wetland uplift due to earthquakes (e.g. raising of seabed around Wellington Harbour and Porirua Harbour and draining of wetlands in the Hutt Valley resulting from movements on the East Wairarapa Fault in 1855)
- Seabed and terrestrial-land changes in hydrology and geomorphology resulting from volcanism (e.g. ongoing changes resulting from activity of the offshore White Island Volcano, Bay of Plenty)
- River mouth migrations that are natural responses to natural changes in sediment supply, floods and low flow events
- Natural cycles of erosion and accretion on soft-sediment coasts that are the result of natural changes in long-term average sea conditions and climate

The QINCCE methodology uses two hydrological and geomorphological parameters for terrestrial and aquatic environments:

- The score representing the magnitude of each change to the hydrology and/or geomorphology compared to the "*present-potential natural state*"
- % area [in each unit] affected by each hydrological and/or geomorphological change

The changes referred to are those mediated by humans and their activities (e.g. (Suren & Elliott 2004; Reid et al. 2008; Campbell 2010). Hydrological and geomorphological changes may occur together. Examples include: dune flattening which removes the dune swales with the associated wetlands and lakes; bulldozing a river mouth to a different location affects both hydrological and geomorphological processes; and draining and filling wetlands.

7.4.3 Addressing disturbance effects on present-potential cover and present-potential natural state

Natural disturbance plays an important role in New Zealand aquatic and terrestrial ecosystems at a variety of spatial and temporal scales (Wardle 1984; Mosley 2004; Winterbourn 2004; Martin & Ogden 2006). New Zealand's position on the edge of the Australian and Pacific plates means that it is geologically active. As a relatively isolated archipelago in the stormy Southern Ocean, much of New Zealand has a relatively changeable climate with a propensity for high winds, and with some locations experiencing periodic intense rainfall.

While there are periodic large-scale catastrophic disturbances, most disturbances occur at the level of the patch or collection of patches. The patch-dynamics paradigm proposes that ecosystem patterns and processes take place within different sized patches that are defined by abiotic and biotic factors that change over time and space (Wu & Loucks 1995; Zimmerman et al. 2010). The role of gap-phase dynamics in ecosystem composition and processes at the patch scale has been explored in a variety of ecosystems. In an investigation of four tropical forests Feely et al. (2007) found that natural biomass losses were concentrated in rarer later-phase forests and biomass increases were more gradual and concentrated in earlier phase patches. A quantitative assessment of the ecological impacts of a hurricane with a forty year return period for a mid-succession deciduous temperate forest found that greater large-tree mortality than occurred between storms (when small-tree mortality prevailed) (Busing et al 2009). The spread of damage varied with some patches remaining undamaged. As some early succession species (pines) were less damaged it was anticipated that the initial divergence in forest composition resulting from the storm would lead to further divergence from pre-storm compositional patterns and trends. This divergence was likely to be further exacerbated by introduced species which had increased following the storm.

The QINCCE methodology for measuring natural character and its change uses protocols to address natural disturbance. In the core parameter *Score for* p*rogress towards present-potential cover*, *present-potential cover* is reset to reflect the new physical conditions and timing of natural disturbance. Distinguishing between natural and human disturbance is also important for the core parameters addressing hydrological and geomorphological naturalness.

Much, disturbance in the coastal environment is human-induced. It can be confined to the area directly disturbed (on-site) or it may extend well beyond this (off-site). Fishing methods based on dredging and trawling are examples of human on-site disturbance to marine sediments, infauna and structure-forming species (Watling & Norse 1998; Turner et al. 1999; Thrush & Dayton 2002). Aquatic sites are often affected by off-site human activities leading to changes in the amounts, characteristics and timing of water and sediment reaching a site. For example, catchment land use activities (such as vegetation clearance and the construction of roads) can lead to accelerated sedimentation in downstream “off-site” freshwater and marine environments. A flow-constricting structure such as a causeway changes sediment deposition patterns, especially up-current of the structure.

There may be a long period of off-site adjustment following human hydrological, hydraulic and geomorphological disturbance at a site that is typically up-stream or up-current. For example, in the Firth of Thames (northern New Zealand), an area that was previously intertidal sand flat was transformed by the deposition of millions of cubic metres of mud following catchment deforestation. Deforestation largely occurred from the 1850's to the 1920's. Mangrove colonisation began in the 1950's when the surface elevation reached 0.5m above mean sea level. Mangroves now extend 1km seaward of their 1952 seaward boundary (Swales & Bentley 2008). While sedimentation rates have slowed (the amount deposited in the 36 years to 1918 is equivalent to 280 years at current sedimentation rates), rates are still high (Swales & Bentley 2008). Over the last 60 years sediment accumulation rates have been approximately 20mm/year, but 100mm/year on the seaward edge of the mangrove forest (Swales et al. 2007; Swales & Bentley 2008).

Sometimes it can be difficult to determine whether the causes of a disturbance are natural or human-induced. This is most likely to be the case for historical disturbance. For example, in some parts of North America it can be difficult to distinguish between historical fires that were natural (primarily lightening induced) and those resulting from the activities of American Indian populations (Landres et al. 1999). In contrast, New Zealand has an internationally low level of damaging lightning strikes, natural fires were historically rare, and prior to human arrival were likely to have been small (McGlone 2001). Pollen records and soil-charcoal show large scale environmental change resulting from extensive anthropogenic fires (McGlone 2001) following initial human settlement in New Zealand (McGlone & Wilmhurst 1999).

In the marine environment it can be difficult distinguishing between human disturbance to natural ecosystems resulting from the human harvest of large quantities of some species versus large scale natural fluctuations due to changes in currents, recruitment variation or other factors. Where human harvest focuses on keystone species (e.g. snapper (*Pagrus auratus*) in northern New Zealand) this can lead to a trophic cascade of effects throughout the ecosystem (Shears & Babcock 2003). Even the harvesting activities of indigenous peoples can disturb marine ecosystems (Jackson 2001). There is evidence that locally Maori harvested large amounts of sea food (Lee 1983; Parsons et al. 2009) including the use of nets up to 2000 feet long (Captain Cook's journal as cited in Lee 1983).

The complexities associated with disturbance directly impact on the scoring for three QINCCE core parameters:

- Score representing progress to *present-potential cover*;
- Score representing the magnitude of each change to the hydrology and/or geomorphology compared to the *present-potential natural state*
- % area [in each unit] affected by each hydrological and/or geomorphological change

Protocols specify how these parameters should be addressed for different disturbance contexts (especially hydrological and geomorphological disturbance) (Table 7.1). Distinctions are made between: natural and human-induced disturbance; impacts from on-site and off-site disturbance; and changes resulting from human-induced disturbance and restoration activities. Major on-site disturbance that converts aquatic environments to dry land and vice versa is specifically addressed, including protocols for scoring situations where the structures that changed the hydrological status are no longer maintained or abandoned.

A dramatic increase in fine sediments resulting from human activities in catchments is a common off-site impact in many aquatic coastal environments. This has affected many northern estuaries and other sheltered waters. In the Firth of Thames more than one metre of fine mud has accumulated in places on top of former sand flat (Swales & Bentley 2008). In these places mangrove vegetation now forms the cover because this new substrate provides the conditions that suit mangroves. Table 7.1 specifies the protocols for scoring the off-site impacts resulting from human-induced catchment disturbance, while Appendix 5 provides guidance on determining *present-potential cover* for estuaries and harbours in Northland.

Table 7.1: Protocols for addressing different types of disturbance for the hydrological and geomorphological naturalness and progress to present potential cover parameters:

Specific parameters addressed:

- Score representing progress to present-potential cover
- The score representing the magnitude of each change to the hydrology and/or geomorphology compared to the present-potential natural state
- % area [in each unit] affected by each hydrological and/or geomorphological change

Type of disturbance	**Protocols for addressing disturbance effect on *present-potential cover***	**Protocols for addressing disturbance effects on *hydrological and geomorphological present-potential natural state* and parameters**	**Examples of disturbance type**
Natural disturbance	Reset *present-potential cover* to address new circumstances	Reset *present-potential natural state* to address new circumstances	Storm and earthquake induced landslides Erosion of soft-sediment coastlines during storms/times of large swells (on-site/off-site weather effects)
On-site disturbance by humans	No reset of *present-potential cover*. Use pre-disturbance present-potential cover	No reset of *present-potential natural state.* Score the magnitude and area affected by each hydrological and geomorphological human induced change	Sites where there are direct disturbances e.g.: excavations; sand-mining; on-site drainage, filling; quarrying; underwater dump or dredging
Major on site disturbance by humans that changes aquatic environments to dry land or vice versa. Major structures and/or maintenance retain the altered hydrological regime	No reset of *present-potential cover*. Use pre-disturbance *present-potential cover*. Typically such dry-land areas are covered by structures/paving and/or production land uses and so the scores for progress towards *present-potential cover* would be low. The same applies to new	No reset of *present-potential natural state.* This is at the extreme end of human disturbance to hydrological and often the geomorphological regimes. Score the magnitude and area affected by each hydrological and geomorphological human induced change accordingly	Drainage of alluvial plain wetlands for agricultural production, residential, industrial or commercial land uses Reclamation of intertidal foreshore and subtidal seabed Creation of impoundments for water storage Creation of a canal system in previously dry land (connected to the

Type of disturbance	Protocols for addressing disturbance effect on *present-potential cover*	Protocols for addressing disturbance effects on *hydrological and geomorphological present-potential natural state* and parameters	Examples of disturbance type
	aquatic environments (often impoundments or canals)		sea)
Ceasing maintenance / abandoning structures that either retain: converted dry land; or inundated land in an inundated state	Reset *present-potential cover* to current hydrological and geomorphological regime once maintenance has ceased/ the structures retaining the altered hydrological and geomorphological state have been abandoned	No reset of *present-potential natural state.* Score the nett magnitude (original disturbance minus “reversion” so far) for each human induced hydrological or geomorphological change and area affected	Collapsed seawall allowing natural ecological communities to re-establish on part of the site of a former reclamation of intertidal/seabed Non-maintenance of a drainage system allowing re-flooding of a former wetland system
Off-site hydrological and geomorphological impacts resulting from human disturbance elsewhere	For the affected *Offsite area*: Reset *present-potential cover* to that which matches the new hydrological and geomorphological conditions for the time period that these changed conditions have been in place	No reset of *present-potential natural state.* For the affected *Off-site area*: score the magnitude of each hydrological and geomorphological human induced change	Downstream sedimentation & eutrophication from catchment land use activities Sedimentation upstream of a causeway Changed sediment supply to down-current coastal longshore sediment transport systems caused by up-current sand mining, breakwater or seawalls
Ecological restoration activities in areas previously affected by on-site human disturbance	Use *present-potential cover* for pre-disturbance state or intended long-term ecological outcome	Use pre-disturbance *present-potential natural state*, or intended long-term ecological outcome. Score the % area and nett magnitude (original disturbance minus changes due to restoration actions) for each human induced hydrological or	Restoration planting using ecologically appropriate species; Reflooding of a former wetland by the removal/ blocking of drains

Type of disturbance	**Protocols for addressing disturbance effect on *present-potential cover***	**Protocols for addressing disturbance effects on *hydrological and geomorphological present-potential natural state* and parameters**	**Examples of disturbance type**
		geomorphological change	
Ecological restoration activities upstream or up-current of areas affected by human-induced *Off-site* hydrological or geomorphological disturbance	Reset *present-potential cover* to the pre-disturbance state or intended long-term ecological outcome	Use pre-disturbance *present-potential natural state*, or intended long-term ecological outcome. Score the % area and nett (original disturbance minus changes due to restoration actions) for each human-induced hydrological or geomorphological change	Removal of oyster farming structures to reduce sedimentation inshore ("off-site") of where the oyster farms had been located Upstream riparian retirement from stock grazing with fencing and planting to reduce levels of fine sediment reaching coastal waters Removal of seawalls and other structures to facilitate normal coastal sediment transport processes
Eutrophication caused by nutrient enriched waters where this is the result of human land use activities & discharges	No reset of *present-potential cover.* Use pre-eutrophication present-potential cover	No impact on hydrological and geomorphological *present-potential natural state* as eutrophication is not a hydrological or geomorphological change	Coastal lagoon or estuary eutrophication resulting from nutrient enriched waters (caused by catchment land use activities and discharges)

7.4.4 Introduced biota effects on present-potential cover

Authors discussing potential vegetation rarely address introduced species. This may be because: introduced species can be a minor detail at the broad-scale that many potential-vegetation models operate at; and there is a valid assumption that the climax vegetation (often a synonoun for potential vegetation) excludes introduced species.

Introduced species have had a major impact on New Zealand indigenous ecosystems. New Zealand has a very high level of endemism in both plant and animal species. Seventy percent of land and freshwater bird species and 85% of flowering plant species present in New Zealand prior to human arrival were endemic. Today New Zealand's level of threatened species is rated among the highest in the world (Hitchmough et al. 2007). Since human settlement more than 25,000 plant species, 54 mammal species and about 2000 invertebrate species have been introduced into New Zealand (Ministry for the Environment 2007b). Nationally there are 2390 naturalised vascular plant species compared with 2158 native vascular plant species. Of the naturalised plant species 66% originated as ornamental plants and 22.5% were introduced deliberately for agriculture, forestry or horticultural reasons (Howell 2008).

In 1998 it was estimated that at least 575,000 hectares of high ecological priority protected areas were threatened by major weed invasion (Owen 1998). Throughout New Zealand those biological communities most vulnerable to weed invasion are coastal, freshwater and lowland terrestrial communities as well as tussock grasslands and shrublands (Froude 2002). Coastal indigenous terrestrial ecosystems have been extensively fragmented and weed invasions are an ongoing threat to dunelands, coastal cliff, rocky supratidal areas and freshwater wetlands.

Non-indigenous species are not part of the *present-potential cover* for a unit or site. The scoring protocols for the parameter *Score representing progress to present-potential cover* address introduced species. Typically, ecological communities dominated by introduced species, sit at the lower end of the scoring range. Some introduced plant species are able to persist almost indefinitely in some situations unless environmental conditions change or they are removed by humans. Examples include tree willow species in eutrophic wetlands (where the *present-potential cover* is flax-sedge-rush-reed-shrub wetland) and gorse and pampas scrub on fore-dunes (where the *present-potential cover is* primarily native sand-binders and low stature shrubs).

7.5 Determining present-potential cover for eastern Northland coastal environments

This section discusses the compilation of *present-potential cover* for eastern Northland coastal environments. A range of resources were used to determine general patterns of *present-potential cover* including: LENZ Levels II (Leathwick et al. 2003) and IV (http://koordinates.com/#/layer/1101-land-environments-new-zealand-lenz-level-4-polygons/); present day good examples; historical records; scientific papers addressing pollen records, succession pathways and species ecology; and ecological reports. At more detailed scales of mapping, local hydrological, geomorphological and other site-specific factors are highly relevant.

7.5.1 Overview of relevant national studies and datasets of vegetation patterns

The potential New Zealand forest cover map in Leathwick (2001) is not sufficiently detailed to be of use in determining *present-potential cover* in the Northland coastal environment. This is because the entire eastern Northland study area lies within a single potential forest unit extending well beyond the boundaries of the study area. Whilethe broad-scale map of New Zealand’s potential vegetation cover (Leathwick et al. 2004) provides some guidance it is not sufficiently detailed to directly determine *present-potential cover* for eastern Northland terrestrial coastal environments for use in the QINCCE methodology.

Leathwick et al. (2003) suggested selecting one of the Land Environments of New Zealand (LENZ) classification levels as the context for identifying intact forest remnants in the land environment of interest. The most detailed LENZ level IV classification has 500 environments and is mapped at a scale of 1:50,000. Apart from local areas of volcanic soils, many level IV units in northern Northland are large and may combine coastal and non-coastal areas within a single unit. A major reason for these large and internally heterogeneous units is the lack of detail in some of the data sets underpinning LENZ, especially soils. LENZ largely used the soils data from the New Zealand Land Resource Inventory. This in turn depended on patchy published soils information, general reconnaissance maps, and detailed surveys generally restricted to productive lowlands (Lynn et al. 2009). Much of coastal Northland is not agriculturally productive. The collection of detailed soils data has not, therefore, been a priority.

In the context of the coastal environment there are additional problems with the suggested approach of Leathwick et al. One problem is the possible absence of suitable mature coastal forest remnants that could be used to provide guidance about *present-potential cover* within a particular land environment. In the coastal environment there are a range of situations where local environmental conditions mean that the *present-potential cover* is not forest. Here, the framework provided by LENZ is less useful because of issues relating to scale and deficiencies in some underlying data sets.

Overton et al. (undated) have used vascular plant species observations from plots and Generalised Dissimilarity Modelling to weigh and transform the environmental variables used in LENZ to provide a “next generation” ecosystem classification. Classifications have been developed for trees and shrubs, and ferns and can be expressed using any number of classes between 2 and 400. While this addresses some key defficiences in the LENZ classification (it addresses the lack of weighting between the environmental variables used; if recognises that not all equal-sized intervals along a gradient are of equal importance; and it addresses biogeography) limitations relating to the use of LENZ in Northland’s coastal environments are generally still relevant.

7.5.2 Other information sources

A wide variety of information sources were used to compile information about *present-potential cover* in different types of Northland coastal environment. Indigenous forest is the most widespread *present-potential cover* type for much of terrestrial coastal Northland (Appendix 5 (section 1.1.1). Detail about succession pathways leading to an indigenous forest present-potential cover is presented in Appendix 5, section 1.2). Terrestrial non-forest *present-potential cover* is most common in the Far North and the West Coast (Appendix 5, section 1.1.2). Various freshwater wetland *present-potential cover* options are described in Appendix 5, section 1.1.3).

Detail about present-potential cover for marine environments is divided into that applying to soft sediments (Appendix 5, section 1.1.4) and shallow subtidal reefs (Appendix 5, section 1.1.5). A lack of ecological studies for deeper marine environments meant that it was not possible to compile deep marine environment *present-potential cover* descriptions at this stage.

7.6 Assessing progress towards present-potential cover

The QINCCE core parameter *Score for* p*rogress towards present-potential cover* is assessed for terrestrial and aquatic coastal units. This parameter measures how closely the observed cover (vegetation, benthic cover or non-vegetated surfaces) within a unit matches the *present-potential cover* for that unit. Because the focus is on the level of natural character or environmental naturalness, a unit may include more than one type of *present-potential cover* and/or more than one type of observed cover.

Assessments of progress towards *present-potential cover* require the following information: current cover and present-potential cover. Tables are used to assign a score that represents the difference between current and *present-potential cover*.

7.6.1 Rationale

The rationale for measuring progress towards *present-potential cover* lies in ecological succession/vegetation change theory. Ecological succession is the changes in community structure following a discrete and usually unpredictable disturbance on a site that causes a high level of mortality (Fisher 1990). The earliest succession papers described a sequence of species successively invading a site leading to a climax (e.g. Clements (1916)). Egler (1954) identified two alternative approaches- the first was initial-floristics where all species in the succession were present soon after the disturbance; and the second was relay-floristics, where the later stages of succession entered by colonisation. Connell & Slatyer's (1977) comparison of three models of succession following disturbance found the facilitation model (early species change conditions so that the site becomes more favourable for later species) was prevalent in primary succession, and the inhibition model (all species resist invasions of competitors) was prevalent in secondary succession.

In practice, succession after disturbance is not necessarily linear to a climax "endpoint". There may be a patchwork of disturbance events, such as a series of canopy tree wind-throws in a forest (Ogden et al. 1987), leading to succession processes at a variety of scales with different local-scale species "endpoints". A suggested alternative to the climax is the kinetic concept (e.g. Whitmore (1982) that does not require a stable endpoint and provides for ongoing disturbance and vegetation change. In seeking to avoid the linear implications of the term "succession" Burrows (1990) proposed a theory of vegetation change for a wide variety of circumstances.

At the broad scale, natural ecological systems demonstrate resilience to disturbance by eventually returning to an original "stable state(s)". Humans disrupt this process by: creating new types of disturbances (e.g. large areas of paved surface, constructing causeways and breakwaters); repeating disturbances in environments not designed for such frequent disturbance (e.g. repeated fires in vegetation not adapted to this); introducing new species and harvesting preferred species in large quantities.

While the wording of the parameter *Score for progress towards present-potential cover* may imply a linear route to a single endpoint, this is not the case. A set of protocols (Table 7.1) address natural and human-induced disturbance in the context of determining appropriate *present-potential cover(s)* for a site/unit, and *present-potential natural state* for hydrological and geomorphological naturalness. Parameters relating the present situation to *present-potential natural state* or *present-potential cover* are often assessed at the patch scale.

While many earlier succession studies focused on indigenous forest, ecological succession has been studied in other ecological systems. For example, Fisher (1990) observed that stream succession changes are superimposed on and confounded by daily, seasonal and long-term changes in abiotic factors that cause changes that are not succession changes. He observed that the patchy longitudinal succession downstream of a disturbance has no parallel in forests and suggested some adaptations to make succession theory more applicable to streams. Shallow coastal environments are subject to tidal cycle and other environmental fluctuations that also cause changes that are not succession changes.

7.6.2 Constructing scoring tables for assessing progress towards present-potential cover

The first stage was to determine the various pathways (e.g. Figure 7.3) towards various present-potential covers and the relative timing of different steps along these pathways. Information on the pathways, different stages and their relative timing was available for *present-potential cover* of different types of northern indigenous forest. Such information was patchyfor other present-potential covers. The evaluation of a number of New Zealand ecological/ succession studies (Tables 7.2-7.5 and Appendix 5) identified “stages” in species composition and vegetation size that could be matched to “elapsed time”. The use of “elapsed time” is not meant to imply that changes in biotic cover follow a linear trajectory to *present-potential cover*.

Natural disturbance events at a variety of scales can locally reset *present-potential cover* for the affected area to an earlier developmental stage (Table 7.1). Introduced species can confound natural ecological succession processes – preventing or considerably delaying progress to *present-potential cover*.

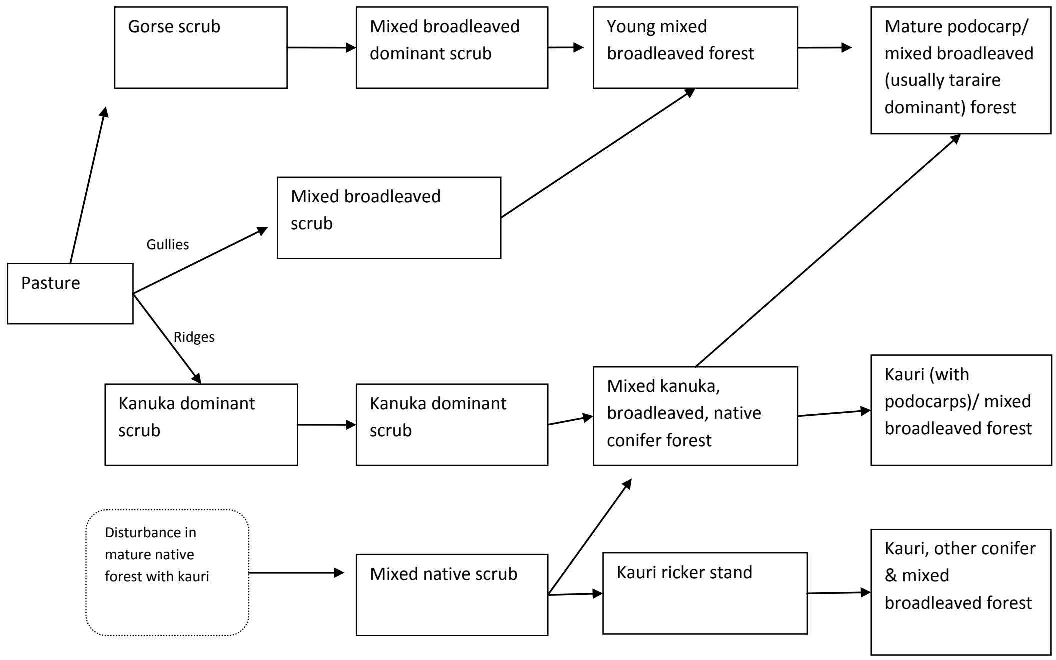

Figure 7.3: Alternative succession pathways leading to a present-potential cover of indigenous forest for northern New Zealand

Before scoring tables could be constructed it was necessary to define an appropriate relationship between the score for progress to *present-potential cover* and "actual" progress as represented by elapsed time or a proxy for that. This relationship was determined by evaluating a variety of ecological succession studies.

Of particular relevance was the work by Molles Jr (2002) who used data from succession studies in different environment types to construct various log-growth curves of time against the number of species. The data sets used included the number of plant species during primary succession at Glacier Bay in Alaska (Reiners et al. 1971); number of woody plant species in secondary succession in the Piedmont Region of the eastern North America (Oosting 1942); number of breeding bird species during secondary forest succession in the Piedmont Region of eastern North America (Johnston & Odum 1956); number of macroinvertebrate and macroalgae species on intertidal boulders following disturbance in southern California (Sousa 1979); amount of chlorophyll *a* (indicator of algae biomass), and the levels of oxygen production and consumption (represent photosynthetic and respiration rates) in stream succession following flash flooding in an Arizona

Creek (Fisher et al. 1982). These data sets graphs generally showed more changes (e.g. increasing numbers of species) occurring during a set amount of time during the early years of succession processes. A much smaller number of changes were observed over the same amount of time in the later stages of the succession process. In a forest bird microhabitat computer simulation project Urban & Smith (1989) demonstrated much higher rates of increase in bird species in the earlier years of forest development. Published New Zealand data (equivalent to that used by Molles Jr. (2002)), showing quantitative trends for a variety of parameters in different ecosystems throughout different succession processes, were not found.

In the absence of readily available New Zealand data, a log-growth curve (as in Molles Jr. (2002)) has been used to represent the relationship between progress to *present-potential cover* and time. This is consistent with the finding by Molles Jr. that more changes occur during a set amount of time during the early years of succession compared to later stages. One outcome of using the log-growth relationship is that the *score for progress to present-potential cover* would reflect changes due to restoration activities more quickly than would be the case if a linear relationship were to be used. This would be most apparent where restoration activities are in locations where *present-potential cover* is native conifer/mixed broadleaved forest and secondary succession to present-potential cover takes about 300 years (Bergin 1979).

Figure 7.4 is a diagrammatic representation of the relationship between the *progress to present-potential cover* (as represented by the score) and the proportion of elapsed time. The score is expressed as a number between 0.01 and 1 where 1 is a precise match (i.e. *present-potential cover* is present). At 300 years (Bergin 1979) secondary succession to native conifer/mixed broadleaved forest is probably the longest of the New Zealand coastal successions across which the 0 to 1 score range is spread.

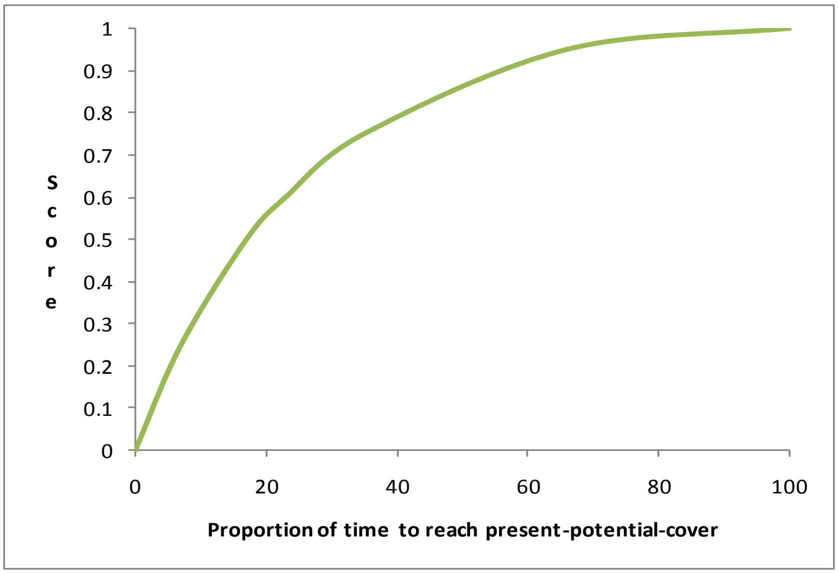

Figure 7.4: Score representing progress towards present-potential cover

The provisional scoring tables for coastal Northland (e.g. Tables 7.2-7.5) have been constructed following the preparation of a synthesis of papers and other information addressing ecological succession processes in coastal Northland and/or other New Zealand locations with similar dominant canopy species (Appendix 5). The scoring tables are most developed for terrestrial environments, especially where the *present-potential cover* is forest (Tables 7.2-7.5). This is because there have been a number of relevant succession studies that can be used to: identify alternative start-points, relative timing of the different "steps" in different situations, and variations that may be specific to particular locations/ environmental circumstances. Terrestrial scoring tables typically provide more detail for earlier succession stages. This reflects a combination of:

- A variety of early options (including "start points") that have different impacts on succession processes
- The impacts of naturalised species that can significantly change or halt succession
- Much recent ecological restoration activity focusing on planting, with most projects still at relatively early stages;
- Difficulties associated with predicting species composition at a particular site for the later stages of succession.

In locations where the succession process is delayed by introduced species the very low score reflects this.

The succession "steps" referred to in the previous paragraph are in reality part of a continuum. They are identified to assist the process of scoring progress to *present-potential cover*. More work is needed before equivalent tables can be constructed for most marine environments. In the absence of robust information, indicative scoring tables have been developed for coastal environments not addressed by Tables 7.2-7.5. These tables contain fewer scoring steps but have been used in field trials.

Within the scoring tables the score increments can vary. This reflects the variability in timing of different stages. It can also reflect variability in amount of available data for constructing robust multi-step scoring tables, especially for some types of *present-potential cover* /environment types.

7.6.3 The procedure for scoring progress to present-potential cover

Assessments of *progress to present-potential cover* and hydrological and geomorphological naturalness require that natural disturbance be distinguished from human-induced disturbances. This can be difficult in complex systems where, for example, a natural disturbance event may have a greater impact because ongoing human-induced disturbance had already reduced the resilience of the system.

The steps for scoring progress to *present-potential cover* for terrestrial and intertidal units are:

- Estimate the proportion of the unit that is *natural area* (NA), *natural surface* (NS), or *biological artefact area* (BAA) (definitions in Chapter 5)
- For each of these categories briefly describe the observed cover using aerial and/or satellite images and inspection as required; determine *present-potential cover(s)*; and score progress towards *present-potential cover(s)* using scoring tables

A similar process is used for the subtidal marine environment (although aerial images are not normally used except for very shallow areas), and the categories of natural area and natural surface are usually combined.

7.6.4 Provisional scoring tables where present-potential cover is indigenous forest

Tables 7.2-7.5 provide the provisional scoring regimes for measuring progress to *present-potential cover* where that cover is indigenous coastal forest. Table 7.2 contains the provisional scoring regime for generic terrestrial secondary succession where the *present-potential cover* is native conifer/mixed broadleaved forest. Table 7.3 provides detail where the succession is via kanuka (*Kunzea ericoides*), Table 7.4 incorporates kauri (although a lack of seed in coastal environments today limits the likelihood of this pathway), and Table 7.5 addresses succession via gorse and/or mixed broadleaved species. For other coastal environments, indicative scoring tables were used in the field trials.

Table 7.2: Generic scoring for progress towards present-potential cover where the present-potential cover is native forest

Score	Threshold or stage	Notes
0	Sealed surface	Includes roads, paved areas, buildings
0.05	Space occupied by dense covering of invasive non-woody species that inhibit native regeneration	Examples include dense kikuyu grass (*Pennisetum clandestinum*), pampas grass (*Cortaderia sellona*), purple pampas (*C. jubata*) and yellow ginger (*Hedychium flavescens*). Ground-based vine species (e.g. ivy (*Hedera helix*) and banana passionfruit (*Passiflora mollissima*) can also inhibit regeneration
0.05	Sites where the cover is predominantly shade-tolerant adventive trees	Shade tolerant species can regenerate under their own canopy, and/or resprout. Examples include monkey apple (*Acmena smithii*), tree privet (*Ligustrum lucidum*) & Chinese privet (*L. senense*)
0.075-0.125	Sites where the cover is dominated by adventive grass species	Includes large lawns, playing fields, paddocks and shrubland (20-80% shrubs) of introduced species. Sites where the soils that have lost structure & organic material and from human-induced causes. including erosion or fire, score least
0.1-0.15	Plantations of shade-tolerant adventive species	Example: Tasmanian blackwood (*Acacia melanoxylon*)
0.1-0.2	Domestic gardens and parklands with scattered trees and shrubs	Gardens dominated by clusters of native species score highest. Natural vegetation is usually scored separately
0.15- 0.2	Dense scrub dominated by shade-intolerant adventive species	Examples. Gorse (*Ulex europaus*), wattles (*Acacia* sp.). For older gorse stands with increasing native scrub species see Table 7.5.
0.2-0.25	Plantations of shade-	Example: Monterey pine (*Pinus radiata*) .

	intolerant adventive species	Dense un-thinned pine plantations have little regeneration and so score at the lower end of the range. Mature thinned pine plantations usually have more understory/native regeneration and so score more highly
0.2-0.3	Naturally regenerated forest dominated by adventive species that do not persist as long term canopy species	Examples include Monterey pine and many wattle species.
0.2	Parkland with native trees (e.g. pohutukawa	Trees < 20% cover typically over introduced grasses
0.15-0.25	Native shrubland in pasture	Shrubland has 20-80% cover of shrubs. Includes recently planted restoration areas
0.3-0.45	Scrub dominated by native species such manuka, kanuka and mixed broadleaved species	See Tables 7.3-7.5
0.2-0.45	Treeland with native tree species	Treeland 20-80% trees over grass (>10cm dbh). Score depends on tree maturity and cover.
0.4-0.55	Young native forest	See Tables 7.3-7.5
0.55-0.8	Intermediate age native forest	
0.85-1.0	Mature native forest	

Table 7.3: Scoring for progress towards *present-potential cover* where vegetation succession is through kanuka to native conifer/mixed broadleaved forest

Score	**Threshold or stage**	**Notes**
0.15-25	Kanuka dominant shrubland	Shrubs 20-80% cover with pasture and/or other low-stature introduced species
0.3-0.35	Kanuka dominant scrub with manuka and possibly other native species	Kanuka establishes on bare surface within 1-2 years, but takes up to 12 years to form a continuous canopy from pasture in Dunedin (Allen et al. 1992) This was measured in the absence of kikuyu which can persist for many years
0.4-0.5	Young kanuka forest	Kanuka was 7m tall at 20 years in the Waitakere Ranges (Esler & Astridge 1974) Between 27 & 50 years kanuka formed a dense stand in Dunedin (Allen et al. 1992)
0.55-0.65	Kanuka canopy thinning with initial entry of other species into the canopy	Kanuka forest stand was 70 years of age in Dunedin (Allen et al. 1992) Kanuka at 100 years of age were 18 metres tall in the Waitakere Ranges(Esler & Astridge 1974)

Score	Threshold or stage	Notes
0.7-0.8	Second stage of other species entering and overtopping the kanuka canopy	Kauri (130 year) that established in the initial kanuka scrub emergent above the kanuka canopy, with rimu (*Dacrydium cupressinum*) following (Lloyd 1960; Esler & Astridge 1974) Kauri average 100-200 years before starting to develop their crowns in the Coromandel (Burns & Smale 1990)
0.85-0.95	Relatively mature broadleaved canopy with podocarps and/or kauri	No kanuka remains in the canopy
1.0	Mature mixed classical mixed broadleaved canopy with emergent kauri (*Agathis australis*) and/or podocarps	Taraire (*Beilschmedia taraire*) is the dominant component of the broadleaved canopy in Northland This takes several hundred years (Esler & Astridge 1974; Allen et al. 1992) The average kauri lifespan is 600 years, Trees with a dbh >2m are >1000 years of age (Ahmed & Ogden 1987)

Table 7.4: Provisional scoring for progress towards *present-potential cover* where kauri is the *present-potential cover*

Score	Threshold or stage	Notes
0.65-0.74	Dense kauri ricker stand	Reported as developing where there has been large scale disturbance (Ogden et al. 1987) and presumably a seed supply. Probably more likely on drier ridges away from coast. Higher scores are for older stands
0.75-0.84	Dense kauri ricker stands thin and increasing amounts of broadleaved species enter the canopy. Kauri beginning to develop mature crowns	Kauri begin to develop mature crowns (at 100-200 years in the Coromandel (Burns & Smale 1990)
0.85.-0.95	Kauri and broadleaved forest, kauri generally with crowns still maturing	
1.0	Mature kauri with some podocarps (e.g. rimu) and broadleaved species (e.g. hinau)	"Climax" stage for succession in studied area of Coromandel (Burns & Smale 1990)

Table 7.5: Variations to scoring resulting from succession via gorse and/or mixed broadleaved scrub

Score	Threshold or stage or state	Notes
0.1	Dense gorse scrub	
0.2-0.35	Older gorse scrub with native species beginning to enter the canopy	Nearer human settlements other adventive species may also enter the canopy (Sullivan et al. 2007). Highest scores are for mature vegetation with little gorse
0.35-0.45	Mixed native broadleaved scrub	In Northland this typically includes combinations of karamu (*Coprosma robusta*), mahoe (*Melicytus ramniflorus*), mapou (*Myrsine australis*), and five-finger (*Pseudopanax arboreus*). This may establish directly (especially in gullies) or via gorse
0.5-0.65	Low mixed native broadleaved forest including towai and rewarewa	Towai (*Weinmania silvicola*) and rewarewa (*Knightia excelsa*) tend to be more common where succession has been via gorse. Bergin (1979) reported kamahi in the Kaimai Ranges, but towai is the northern equivalent
0.7-0.8	Medium age mixed native broadleaved forest including kohekohe, taraire, mahoe	Bergin (1979) reported tawa in the Kaimai Ranges, but taraire is the northern equivalent
0.85-1.0	Mature mixed native broadleaved forest (especially taraire)with podocarps	This takes about 300 years (Bergin 1979)

7.7 Conclusion

Present-potential cover and *present-potential natural state* are useful generic reference condition descriptors. They have been developed for use in parameters that contribute to QINCCE natural character sub-indices. There are protocols on the treatment of different types of disturbance in the context of these generic reference conditions.

While the identification of *present-potential cover* can often be relatively straight-forward where forest is the *present-potential cover*, it can be more difficult in some other situations. In particular it can be difficult to accurately determine *present-potential cover* at or close to particular land-water margins that are subject to frequent natural disturbance. Examples include foredunes, estuary mouths and smaller coastal wetlands. Collectively these areas occupy a relatively small proportion of the coastal environment. Work is ongoing to refine the accuracy of *present-potential cover* determinations in these difficult areas. Further work is also needed for deeper marine environments.

The framework for evaluating progress to *present-potential cover* has been most thoroughly developed for situations where the *present-potential cover* is indigenous coastal forest. This reflects the greater abundance of information and the long time it takes for succession to mature indigenous coastal forest. Further work is needed to refine scoring tables for aquatic and non-forest ecosystems.

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8 Using comparison between “informed” perception and objective measures of natural character to refine methodology for measuring natural character

Abstract

This chapter compares perceptions of natural character by “informed” participants, with quantitative assessments using a set of selected biophysical parameters. The primary reason for doing this was to refine the Quantitative Index for measuring Natural Character of the Coastal Environment (QINCCE) methodology that has been developed to measure the natural character of New Zealand coastal environments.

There can be considerable variation as to how different people perceive the level of natural character of a particular area. This is because an individual’s perception of natural character or environmental naturalness depends on the interaction of the actual biophysical elements, the individual’s sensory acuity, their knowledge and experience, and a variety of personal and cultural factors (Froude et al. 2010). To reduce this variability “informed” (rather than general public) participants scored their perceptions of natural character for each of 40 coastal photographs. Trimmed means of these perceived natural character scores were compared with natural character scores calculated using the QINCCE methodology’s *Viewpoint* perspective.

A major area of methodology refinement involved testing and refining options for the formulae used for the three natural character sub-indices (Environmental Naturalness Index (ENI), Hydrological and Geomorphological Naturalness Index (HGNI) and Freedom from Buildings and Structures Index (FBSI). For the overall Natural Character Index (NCI) options for differential weighting of the three component sub-indices were tested.

Even though “informed” participants were used there was considerable variation between participant natural character scores, especially for some photographs.

Certain attributes of the participants affected their natural character scores, especially for some photographs.

8.1 Introduction

The Quantitative Index for measuring Natural Character of the Coastal Environment (QINCCE) methodology (chapters 5-7) measures carefully selected biophysical parameters that represent components of natural character and integrates the results in a set of indices. The first stage in developing the methodology was to develop a comprehensive definition of natural character (Froude et al. 2010, chapter 3). This was compared with case law (chapter 4) and used as the basis for selecting indicators and associated parameters. There are three sub-indices: Environmental Naturalness Index (ENI), Hydrological and Geomorphological Naturalness Index (HGNI) and Freedom from Buildings and Structures Index (FBSI). These are combined into an overall Natural Character Index (NCI).

The overall purpose of the work described in this chapter was to assist with: determining the relationships between the three sub-indices in the NCI; and refining the parameter set and scoring regimes. This purpose has changed over the course of this research. Initially the priority was to determine how “informed” participants scored the impacts of buildings, structures and paved/sealed surfaces relative to levels of ecological naturalness. The intention was to use these results to determine the relationships between the sub-indices in the NCI. After considerable analysis and testing the initial purpose was expanded to include refinement of the parameter sets and the scoring regime used for some parameters. A secondary purpose was to assess, within the scope of the primary purpose, whether there were differences in the perceptions between different “subgroups” of “informed participants”.

Terrestrial, intertidal and water surface coastal environments are addressed in this chapter. While the QINCCE methodology also applies to subtidal environments, these were not addressed in this part of the research for reasons for this are discussed later.

This chapter begins with a review of literature relating to human perception of natural character/environmental naturalness, and landscapes/landscape quality more generally. The next section reviews methodologies used by others for determining human perception of natural character/environmental naturalness and landscape quality. It then discusses the methodology used in the current research. Analyses of the results are presented and reviewed. Implications, especially for the refinement of the QINCCE methodology are discussed. Potential factors that may account for at least some of the between-participant differences are analysed. Suggestions for future research and methodology improvements are discussed.

8.2 Human perceptions of natural character

Human perceptions of natural character/environmental naturalness are influenced by the distribution, structure, composition, spatial pattern, and functioning of biophysical elements in the environment concerned. These biophysical elements include geomorphology, hydrology, hydraulics, soil/substrate, water, air, biota (native and introduced), biological associations, physical and ecological processes, human structures and sounds, and the patterns in which the various elements are arranged. While various biophysical elements can be measured, people vary in how they perceive the naturalness of individual elements as well as overall environmental naturalness/natural character. This is because an individual's perception of natural character/environmental naturalness depends on the interaction of the actual biophysical elements, with that individual's sensory acuity, knowledge and experience, and a variety of personal and cultural factors affecting that individual (Froude et al. 2010).

8.2.1 Perceptions of environmental naturalness and factors affecting those perceptions

The literature on human perception of environmental naturalness mostly addresses the perception of the general population rather than those who are "informed" or have a good understanding of what makes an environment/area more natural. As members of the general population have not normally spent time considering what makes an area natural they can find it difficult to identify the attributes of environmental naturalness. For example, Hull et al. (2001) found local residents had difficulties defining what made their nearby forest natural and viewed people and the history of the human use of the forest to be part of the "natural forest".

A number of studies have addressed differences between various sub-groups in their perception of environmental naturalness. Habron (1998) found considerable variation in perceived naturalness between rural inhabitants and recreational users in Scotland. Distinct cultural differences were found in a ten country survey of student perceptions of riverscapes, and in particular the role of large in-channel wood (Le Lay et al. 2008). Students from China, India and Russia perceived riverscapes with large amounts of in-channel wood as not natural and considered that those rivers needed management to reduce their danger levels. In contrast students from Germany, Oregon State (USA) and Sweden considered that human-regulated channels needed improvement to increase their naturalness and aesthetic qualities. Le Lay et al. (2008) suggested an explanation for this difference could be that the first set of countries had a 'development strategy' that focused on controlling nature while the second group focused more on living and working with nature.

Several studies have used factor analysis techniques to identify "naturalness perception sub-groups" based on participant scoring or sorting of photographs. In their assessment of public perceptions of natural character in Coromandel (New Zealand), Fairweather & Swaffield (1999) identified two perception sub-groups. The first group ("Factor 1") perceived "natural" to be an absence of human construction and artefacts. For this group, the most unnatural landscapes were those with buildings while treeless pasture was assessed as neutral in terms of its naturalness. The second group ("Factor 2") attributed naturalness to native vegetation. For them, large scale commercial plantation forestry was perceived to be least natural, because of its potential impacts. Treeless pasture was also considered relatively unnatural and limited environmentally sensitive development in natural settings may be acceptable.

In a similar type of study in the tourism locations of Kaikoura and Rotorua, Newton et al (2002b) also identified two perception sub-groups. They called the first “pure nature”. This emphasised nature’s wild attributes or natural character without humans. The second group they called the “cultured nature” view. This is a perception that nature is primarily a resource for human enjoyment and activity, and naturalness is defined in terms of personal experience of the natural environment (Fairweather & Swaffield 2003).

Some studies have compared perception with biophysical measures of naturalness (e.g.Lamb & Purcell 1990; Wagner & Gobster 2007). Most of these studies have not specifically sought participants that were “informed” about what is natural in the context of what is being assessed. In a study of perception of Australian vegetation types and disturbance regimes, Lamb & Purcell (1990) found that while ecological naturalness and perceived naturalness were related there were some important differences. For example:

- Heath vegetation was perceived as less natural than forests and even severely weed-infested forests were seen as natural
- Where foliage cover was sparse, all levels of human interference were perceived as equally unnatural. As the density of foliage cover increased, participants were increasingly unable to discriminate between levels of interference
- As vegetation height increased people became less able to discriminate between natural and altered vegetation. Extensively altered structure in the tallest forest was perceived to be more natural than low stature vegetation with minor modification

In a very different study by Taylor et al.(2011 in prep) to establish naturalness baselines, long-term divers were asked to use only their memory and dive logs to recollect changes in particular species and ecological communities found in the waters of the now Poor Knights Marine Reserve (New Zealand). The divers were asked to record relative abundance for each of the species and communities in each of four time periods beginning with “pre-1971”. When diver recollections were compared with the far more limited (in terms of the span of time covered) monitoring data, Taylor et al. (2011 in prep) found that the divers were not inconsistent with the monitoring data and were conservative in their assessments of change. The authors observed that most of these participating long-term divers had a good knowledge of marine life. They could, therefore, be considered to be "informed" from the perspective of assessing naturalness.

Other authors have considered perceptions of environmental change, but in terrestrial environments. Several authors have found that those who experience rural natural riparian areas more frequently tend to observe more of the changes that occur (Zube et al. 1989; Wagner & Gobster 2007). Zube et al. (1989) found that when people do not understand the linkages between parts of a natural system they may not appreciate the effect of environmental changes on attributes they value. Wagner & Gobster (2007) found differences between traditional biophysical landscape change assessments and how residents experienced and interpreted environmental change.

8.2.2 Perceptions of landscape quality

The term "landscape quality" is associated with different interpretations/paradigms. Some authors have focused on the development of an objective method for its assessment by experts (Daniel & Boster 1976; Tveit et al. 2006). Others have preferred to use psychophysical methods to determine overall public assessments of "landscape quality" (Fairweather & Swaffield 2002; Newton et al. 2002a). Landscape preference typically refers to the landscapes preferred by individuals or groups. It is related to "landscape quality" and is affected by a number of factors

Many studies have sought to identify factors affecting human preferences for particular landscapes and landscape quality. A review by Kaplan & Kaplan (1989) found that the most preferred scenes reflected mystery (a promise of further information), and that legible (easily understood and remembered) scenes were highly favoured. Scenes with relatively little coherence or complexity (attributes required for the immediate processing of information) were least favoured. Kaplan & Kaplan (1989) related these preferences to effective human functioning. Very open scenes with few differentiating elements (little protection and few landmarks for orientation) and those with dense vegetation (hard to move and a sense of hidden danger) were least preferred, while relatively uniform trees with low ground cover were considered to increase security and competence. Haggerhall (2001) found a high degree of consensus in landscape preference where there was a strong commonly-shared idealised image for a preferred landscape (e.g. the Swedish traditional pastoral scene for Swedes).

There appear to be preference differences between ethnic groups with signs of human influence, neatness and openness being far more important to some ethnic groups than others (Kaplan & Kaplan 1989). Age can also affect landscape preference (Balling & Falk 1982; Miller 1984). While familiarity can affect preference, it is not necessarily the familiar environment that is preferred (Kaplan & Kaplan 1989). Where there is a greater knowledge and concern for indigenous species this has been shown to increase the preference for intact indigenous landscapes. Kaplan & Herbert (1987) compared landscape preferences of Australian and American students with Australian members of a group with an interest in Australian flora. While they found some differences in preferences between Australian and American students that could be attributed to familiarity, there were larger differences between the Australian students and members of the group with an interest in Australian flora with the latter group showing higher preferences for indigenous landscapes. The members of the group with an interest in Australian wildflowers are “informed” participants from the perspective of assessing environmental naturalness.

8.2.3 Relationship between environmental naturalness and landscape quality

A number of authors have reported that naturalness enhances landscape preferences (Purcell & Lamb 1984; Urlich 1986; Kaplan & Kaplan 1989; Purcell & Lamb 1998; Haggerhall et al. 2004). Naturalness was one of nine key visual elements identified by Tveit et al. (2006) in a framework for analysing visual landscape character. Waterscapes are often among the most highly preferred landscapes (Purcell & Lamb 1984; Kaplan & Kaplan 1989) and this may partly be due to their contribution to perceived naturalness.

For the general population, the relationship between naturalness and preference is not linear (Tveit et al. 2006) and the degree of actual naturalness may be less important than perceived naturalness when determining landscape preference (Purcell & Lamb 1998). Nassauer (1995) observed that for many in North America, the picturesque can seem to be so part of nature that often it is mistaken for ecological quality or naturalness. This leads many to prefer landscapes that look cared for, rather than those that are truly "natural". However, increased knowledge about what is natural, including good knowledge about indigenous plant species, has been shown to increase preference for intact indigenous landscapes (Kaplan & Herbert 1987).

8.3 Using psychophysical methods to measure human perceptions of landscape quality and environmental naturalness: literature summary

I used the psychophysical approach for my research into the natural character perceptions of "informed" participants. The psychophysical approach has been one of the two most commonly used approaches for assessing landscape quality (Zube et al. 1982). In this approach landscape aesthetic values are evaluated by selected populations of the general public. The other common approach is the expert paradigm where landscape quality is evaluated by professional observers. In a comparison of these two approaches or paradigms from the perspective of assessing landscape quality, Lothian (1999) stated that the expert paradigm assumed "landscape quality" to be an intrinsic physical attribute while the psychophysical paradigm considered it to be a human construct (with beauty being in the eye of the beholder). He concluded that for the identification of landscape quality, the psychophysical approach was scientifically and statistically robust and offered predictive capacity.

The divergence between expert and public assessments of landscape quality/preferences has been observed by several authors including: Anderson (1978) for forest harvest, regeneration methods and land management practices in the USA; Ellsworth (1982) for marsh and river tributaries in Utah; Hudspeth (1986) for urban waterfront views; Medina (1983) for urban environments; and Miller (1984) for shorelines in British Columbia, Canada.

My research does not address landscape quality. Its focus is public perception of natural character/ environmental naturalness. While many studies have used psychophysical methods to determine public landscape preference and/or quality, a much smaller number of studies have sought public assessments of environmental naturalness or natural character. The purpose of this methodology literature summary is to review the different psychophysical methods that have been used and thereby inform the detailed design of the methodology used in this research. As this is a review of methodology design, studies assessing public perception of landscape quality and preference are included as well as studies addressing perceptions of naturalness.

8.3.1 Overall approach

Those using psychophysical methods to obtain data on public perceptions have typically asked participants to assess items or images using one of the following approaches:

- A series of paired comparisons
- Rating or scoring on a fixed scale (magnitude estimation)
- Ordering or sorting from high to low for some characteristic(s)

The Law of Comparative Judgement (LCJ) (Thurstone 1927) is a model that can be used to scale data on the perceived intensity of physical stimuli or attitudes based on a series of pair-wise comparisons. Paired comparisons can be used to determine the psychological values of objects (Thurstone 1929) and preferences (Hull & Buhyoff 1981). This approach can be time-consuming. Buhyoff et al. (1981) estimated that the LCJ computation of scale scores for 15 landscape attributes, using paired comparison data would require participants to evaluate 105 pairs of images. This is more than most participants would be prepared to do.

The Scenic Beauty Estimation method (Daniel & Boster 1976) uses the second approach. Aesthetic perception responses of participants are transformed using the Scenic Beauty Estimation Model to give standardised values that allow the responses of different participants to be more directly compared. The subsequent Scenic Beauty Prediction Model (Daniel & Schroeder 1979) is based on an assumption of a consistent relationship between people's perceptions of a landscape and specific properties of that landscape. As previously discussed, such an assumption may not be valid. An equivalent to the Scenic Beauty Prediction Model of Daniel and Schroeder (1979) was developed by Mosley (1989) to predict the scenic attractiveness of New Zealand's rivers. Mosley's model was based on particular physical characteristics of New Zealand's rivers and the landscapes within which they are found.

A number of studies have asked participants to use a fixed scale to score their landscape preferences in photographs (e.g.Daniel & Boster 1976; Shafer & Brush 1977; Mosley 1989). Australian assessments of public perceptions of naturalness (e.g. Lamb & Purcell 1990; Purcell & Lamb 1998; Williams & Cary 2002) have typically asked participants to score naturalness using a fixed scale.

In Magnitude Estimation (ME) people assign absolute numbers based on the perceived intensity of the matter being assessed. Buhyoff et al. (1981) extended the application of this method to the multidimensional concept of landscape preference. Participants twice ranked a small set of images along a 3m table marked into 100 sections. The first time was to identify the lowest ranked image. For the second time the centre arrow of the lowest ranked image was placed on the zero mark and participants placed the centre arrows of the remaining images along the scale such that the distance between the centre-arrows represented the magnitude of the difference in their preference for those images. If participants did not use the full 100 point scale their scores were standardised to 100 percent. These standardised scores were averaged and a ME score was calculated for each photograph.

While Buhyoff et al. (1981) found that the results obtained using the modified Magnitude Estimation methodology were very similar to those obtained using more complex methods, there are a number of disadvantages. These include: the requirement for participants to score the same images twice so taking more time; a requirement for a large number of expensive colour prints; the ranking of images required for the first assessment limited the number of photographs that could be used; and unsuitability of the method for assessments by groups. Because of these disadvantages this was not a favoured approach for the current study.

Several New Zealand researchers (e.g. Fairweather & Swaffield 1999; Newton et al. 2002) have used the Q method (McKeown & Thomas 1988) where participants order or sort landscape photographs in order of preference or perceived naturalness. Such an ordered set of photographs is called a “Q sort”. This sorting of objects according to an instruction can be used more widely to determine groupings of people based on their ideas or preferences and was originally developed for political science analyses (of statements). The Q sorts from the different participants are factor-analysed to identify several groupings of people who sort items in a similar way. The factors (or groupings) are often personalised and people who are part of a factor grouping are said to load onto that factor (Newton et al. 2002). In the study by Newton et al. (2002) approximately 70 percent of the participants were assigned to one of two factor groups.

This Q method approach is largely qualitative and is not widely used elsewhere for perception studies, although (Palmer 2004) reported the use of the Q sort methodology in the mid 1970s for evaluating the scenic quality of 56 photographs of Dennis, Massachusetts. Twenty years on the sites were rephotographed and a different set of residents scored both sets of photographs using a ten point scale rather than using the original Q sort methodology.

8.3.2 Photograph sets, scoring regimes and participants

Those using psychophysical methods (Pelli & Farell 1995) to determine participant perceptions of environmental naturalness or preferences of landscape quality typically use photographs. A review of 26 (mostly North American) studies (Kaplan & Kaplan 1989) found that the number of photographs used ranged from 14 to 191. Most studies used between 40 and 80 images. Only two studies used more than 100 images. The number of participants ranged from 18 to 660 with an average of 208. Images were typically scored using a five point scale although some used an alternative range (e.g. 10 point). In some studies images were sorted by preference. In a New Zealand study (Mosley 1989) participants scored 100 colour slides of river scenes for their scenic attractiveness on a ten point scale and for their suitability for one of 17 recreational activities. There were 400 people from 18 groups. Buhyoff et al. (1981) used ranking to establish the low point and then participants were asked to score photographs using a 100 point scale.

Studies addressing perception of environmental naturalness typically ask participants to rank or score the naturalness of photographic images representing scenes (e.g. Lamb & Purcell 1990; Fairweather & Swaffield 1999; Purcell & Lamb 1998; Le Lay et al 2008). Light and composition protocols are standardised to limit the impact of these factors on participant scoring. Typically the photographs used in Australian studies have excluded built structures (e.g. Lamb & Purcell 1990; Purcell & Lamb 1998; Williams & Cary 2002) as the primary focus of these studies has been to determine participant perceptions of the naturalness of different types of vegetation and modifications or disturbances to that vegetation. In contrast, New Zealand studies have typically used broad-based photograph sets (e.g. Fairweather & Swaffield 1999 & 2003; Newton et al. 2002) that include different types of land use and structures.

As previously described participants in published New Zealand studies have generally ordered or sorted photographs in order of perceived naturalness (Fairweather & Swaffield 1999; Newton et al. 2002; Fairweather & Swaffield 2003). Table 8.1 summarises the methodology used in Australasian psychophysical studies of naturalness perceptions.

Table 8.1: Summary of methodology detail used in published Australasian studies of naturalness perception

Author(s)	Number of photos	Number of participants	Type of assessment by participants
Lamb & Purcell 1990	71	81	Score each image from 1 to 130
Purcell & Lamb 1984			Score each image using 10 point scale
Purcell & Lamb 1998	96	49	Score each image from 1 to 100
Fairweather & Swaffield 1999	51	88	Q sort in order of preference
Fairweather & Swaffield	2 X 2 pairs	280	Select most natural in each of 2 pairs

Author(s)	Number of photos	Number of participants	Type of assessment by participants
2003`			
Williams & Cary 2002	36	664 + 568	Score preference from 1 to 5
Newton et al 2002	Not given	123	Q sort in order of preference

The number of photographs (40) used in thecurrent study was at the lower end of what has been used for equivalent Australasian studies and studies reviewed in Kaplan & Kaplan (1989). Participants scored their perceptions of levels of natural character (naturalness) using a 100 point scale. Magnitude estimation using a fixed scale is the most common approach found in the international literature. It also provided the type of quantitative information needed for the current project. Compared to the Q methodology which focuses on the attitudes of the participants, magnitude estimation focuses on the attributes of the environment. The number of participants used in the current study (113) was around the median used for other Australasian studies.

8.4 Refining QINCCE formulae: using psychophysical methodology to determine the naturalness perceptions of "informed" participants

The overall purpose of this section of work was to assist with: determining the relationships between the three sub-indices in the NCI (refer Box 8.1); and refining the parameter set and scoring regimes. This was done by comparing perceptions of naturalness from selected "informed" participants with quantitative assessments using the QINCCE *Viewpoint* methodology (Box 8.1).

The reason for using participants that were informed was that participant perceptions were being used to refine the construction of the QINCCE formulae. It would not be appropriate to use "uninformed" participants for this. In addition the current project was not seeking to assess overall public perceptions of natural character.

Box 8.1: Summary of the QINCCE (Quantitative Index for measuring Natural Character of the Coastal Environment) methodology

A consistent methodology is used across terrestrial, freshwater and marine coastal environments. For the primary or plan-view methodology relatively homogenous units from the perspective of natural character are depicted manually and subsequently digitised at a scale appropriate to the assessment purpose and information available. For each broad class of coastal environment there is a core suite of parameters which are used to calculate the following three sub- indices for each unit: ecological naturalness index (ENI); hydrological and geomorphological naturalness index (HGNI); and freedom from buildings and structures index (FBSI).
These three indices are combined to give an overall natural character index (NCI) for each unit. Tier two parameters are available for those areas or situations where a more comprehensive measurement of a wider range of parameters is required.

A secondary viewpoints methodology can be used in conjunction with the above plan-view based methodology. This uses a grid held at a set distance from the body (section 6.6.1) to provide a quantitative assessment of the percent cover and other parameters (excluding structure height) of the "view".

8.4.1 Compilation of the photograph set assessed by participants

In accordance with many other studies assessing perception of environmental naturalness or landscape preference (Daniel & Boster 1976; Shafer & Brush 1977; Purcell & Lamb 1984; Mosley 1989; Purcell & Lamb 1998; Williams & Cary 2002), the participants in the current project scored their perceptions of each photograph for a set of photographs. In the current study participants scored what they perceived to be the level of natural character represented in each photograph. A meta-analysis of 19 studies (Palmer & Hoffman 2001) found that the use of photographs was generally valid for assessments of scenic quality although the photographs may not always accurately represent the conditions in the field. In the context of the current study this qualifier is not a major concern because both the calculated natural character scores (section 8.4.5) and the participant scores are based on the same photographs. It was not necessary for all the details of specific locations to be faithfully reproduced in the photographs.

The set of photographs used in this study was limited to 40, including the controls. This was at the lower end of what is commonly used for such studies (e.g.(Kaplan & Kaplan 1989; Mosley 1989) and Table 8.1) although Table 8.1 shows that there has been considerable variation. A number of participants commented that the use of 40 photographs seemed to be a good number from their perspective and they would not have wanted to assess many extra. Robustness may, however, have been improved had photographs addressing additional types and combinations of coastal environment and human impact been included.

It was difficult to select the final set of photographs to be used in the current study because of the diverse range of New Zealand coastal environments for which the QINCCE methodology was designed, the wide variety of potential human impacts on different types of coastal environment, limits to the number of photographs that participants would be prepared to assess, and the study requirement that the results be applicable across a wide range of terrestrial and water surface coastal environments. The final set was selected from a larger set of more than 200 digital photographs. Some photographs were cropped to remove ambiguities and distractions, especially large amounts of sky.

Criteria used to select potential photographs for inclusion in the final set were that the photograph had to be: correctly exposed and technically correct; free of, or contain minimal sky; taken in generally fine weather; and represent views obtained while on foot or in a small boat (no aerial images). The primary criteria used to compile the set of 40 photographs were that the set was to include:

- A diversity of Northland and Auckland terrestrial coastal environments
- Water surface (marine environment) as a dominant part of a subset of photographs
- “Control” photographs illustrating minimal building and structure impact
- “Control” photographs illustrating intensive and widespread building and structure impact
- A range of building and structure impacts between the two end points addressed by the “control” photographs

- Different types and levels of building and structure impact where there are different types and seral stages of coastal native vegetation cover where that vegetation cover is dominated by native species and/or there is a natural surface (e.g. rock face, unvegetated dune)
- Building and structure impacts where the vegetation cover is dominated by introduced species including pasture and forestry using introduced species

At the time the photograph set was assembled the last bullet point was considered to be of lesser priority and so fewer photographs were included. Some council staff participants considered that it would have useful to have included additional "no-building or structure controls" for coastal environments dominated by introduced species, especially pasture grasses.

The first 28 of the 40 photograph set were of the terrestrial coastal environment. In these images the amount of water was minimised because water is generally considered to enhance perceptions of naturalness (Kaplan & Kaplan 1989). The water surface of the marine environment was a dominant part of the final 12 photographs. No underwater (subtidal) photographs were included. Several of the marine environment photographs included a land component. This was in part due to the difficulty of obtaining suitable images without some land.

The collective terrestrial and marine photograph set incorporated a variety of building and structure impacts in different ecological contexts. The positive controls (4) were of relatively unmodified coastal environments. The negative controls (4) were selected to illustrate a high level of modification due to buildings, structures and paved surfaces. The 28 terrestrial photographs were shown first. These were followed by 12 marine environment (not subtidal) photographs. The terrestrial and marine environment photograph sets each began with a positive and negative control. The other controls were distributed through the photograph set. Participants were told that this would happen and encouraged to make sure that they used the full scoring range. Although other researchers of perception of environmental naturalness/ natural character have used a photograph set representing a range of development levels, those photographs representing "minimal human impact" and highly impacted environments are not usually called "controls".

8.4.2 Selection of participants

As previously discussed, "informed participants" were selected for the current study. "Informed participants" were defined as generally have knowledge and/or experience with aspects of the New Zealand coastal planning regime, and/or involvement/interest in New Zealand coastal management, and/or knowledge of New Zealand natural coastal ecosystems and their functioning. All participants except for university staff and students were from either Auckland or Northland regions. The photographs used for assessment were from these two regions.

There were 113 participants. Some participants had had lengthy involvement with aspects of New Zealand coastal management/planning (e.g. regional council coastal planning staff, members of the (Northland) public who had a long history of involvement with agency coastal planning and/or management). While it had been intended that all participants would be well informed, the selection of groups rather than each individual participant meant that some participants were not as well informed as had been intended.

Groups were used because it would have been very time consuming to contact each potential participant individually and organise a time for doing the assessment. I worked through appropriate contact people in relevant organisations. For district and regional councils I either used a known contact who was involved in coastal management and/or a relevant council manager. This person organised the time and venue, and circulated information I provided to people they thought could be interested and had relevant knowledge or experience. A seminar about my research on natural character and its measurement was offered to, and accepted by, all councils involved. These seminars provided useful feedback from practitioners and helped to encourage participation in the scoring exercise. The councils that participated (during mid-late 2009) were Northland and Auckland Regional Councils, Whangarei and Far North District Councils.

Kaipara District Council (the third district council within Northland Region) was not included because it is a small council that contracts out most planning work to private consultants. Attempts were made to set up a seminar and assessment session with the staff of Rodney District Council (then the most northern district council in Auckland Region) but such a session was not able to be organised.

Representatives of several Northland public interest organisations with a strong interest in the coastal environment were approached and a time arranged within an already scheduled public meeting for participants to take part in the natural character scoring exercise. The first public interest organisation meeting was the September 2009 AGM of the Guardians of the Bay of Islands (Guardians) while the second was the November 2009 AGM of the Bay of Islands Maritime Park (BOIMP Inc). Both meetings included several speakers, the natural character assessment exercise as well as the AGM. Participants included staff from the Department of Conservation and Northland Regional Council as well as members of the public. Where an agency staff member completed a natural character assessment at a public meeting their data was analysed with others from their organisation. For a variety of reasons not all attendees at these two public meetings participated in the natural character scoring exercise. Several participants attended both public meetings but each only participated in the scoring exercise on one occasion.

The last group of participants were from Waikato or Lincoln Universities. Participants from Waikato University were either postgraduate planning students or members of the Science Faculty attending a seminar I presented in the Biological Sciences Department in December 2009. The Lincoln University participants were environmental planning and policy undergraduate and graduate students. Student assessments were associated with lectures.

8.4.3 Procedures used to collect participant natural character assessments and context data

The 40 selected photographs were incorporated into a Microsoft powerpoint slide show with each photograph numbered in the top left corner. The photgraphs are reproduced in Appendix 9. A data projector was used to project the photographs onto a large screen/ area of plain wall. The photographs were shown in quick succession (typically1- 2 seconds per photograph) before being shown more slowly (15 seconds per photograph) for scoring purposes. Other authors have also shown all or some of the photographs before participants begin scoring to ensure that participants have an understanding of the scoring range (Kaplan & Herbert 1987; Kaplan & Kaplan 1989; Lamb & Purcell 1990). Participants scored their perception of the amount of natural character in each photograph using a scale of 0 to 100, where 0 means no natural character is present and 100 means that the photograph represents an area that is completely natural.

Participants were told that the first two photographs were a positive and negative control respectively and that the primary purpose of the controls was to encourage them to use the full range of available scores (i.e. from close to 0 to close to 90-100). They were also told that some photographs had been resized to minimize the amount of sky and that they should ignore the sky in their natural character scoring. Each participant received an ethics consent form (Appendix 8) and a formatted A4 sheet of paper for recording their scores and providing basic background/context information (Appendix 7). The context information sought was:

- Age group, gender, ethnicity, citizenship/residency, and familiarity with New Zealand mangroves (information to be provided in specified categories)
- Tertiary qualification subject area(s), occupation/activities, and experience with coastal management (short written answers requested) where answers to the first two items were later converted into categories)

The short answers for tertiary qualification subject area and experience were later converted into categories for analysis purposes. Answers on coastal experience were too variable to be used for analysis.

Each participant scoring session was preceded by a briefing to ensure that the participants understood what they were to do and why. Briefings are used (e.g. Lamb & Purcell (1990)) to maximise the utility of the resulting data. Matters covered in the briefing included the protocols being used and the definition of natural character. When some participants suggested that would be too difficult to use a 0 to 100 scoring range, I suggested that they treat it as a 20 point range using every 5th number (0, 5, 10, 15 etc.). In practice most participants used single increments at times- especially when their scores were near either end of the 100 point range. In response to questions, participants were informed that there were no intended tricks in the photographs, and that negative scores could not be used even for photographs dominated by large buildings and/or structures (e.g. T12). Once natural character has been removed an area will score zero for natural character. At this stage, further buildings and structures may detract from landscape or amenity values rather than natural character.

After the participants had finished scoring the images, signing the consent forms and providing background data I asked for feedback. In response to a question about the number of images to be scored, participants did not say that there were too many images. Some said they thought the number was about right but they would not have wanted to have scored too many more. Most people seemed to have enjoyed the exercise. Some scoring sessions were followed by a more general discussion addressing issues arising from my earlier presentation and the photograph assessment exercise. Appendix 6 summarises the trials used for developing this methodology and provides detail about the contextual/background information participants were asked to provide.

8.4.4 Analysing participant natural character scores

The data from participants were coded so that names (retained so that people could be informed about the study outcomes) were not associated with the natural character perception scores or the background context data. All relevant data were entered into an Excel spreadsheet, with the text answers grouped into categories to facilitate analysis. Means, trimmed means and confidence limits were calculated along with a variety of other metrics for each of the photographs used. The trimmed means removed the upper and lower 5% of scores for each photograph. This was to remove the most extreme outrider scores from the calculation of the mean for each photograph. Confidence limits could not be calculated for the trimmed means for each photograph. For each photograph, the trimmed means of *participant natural character scores* (PNCS) were compared with the corresponding *calculated natural character score* (section 8.4.5).

8.4.5 Calculated natural character scores

A modification of the QINCCE *Viewpoint* method (section 6.6.1) was used to develop the *calculated natural character score (*CNCS*)* for each of the 40 photographs (Appendix 9) used for assessing perception. A 5 x4 grid was placed over each on-screen computer photograph to facilitate the calculation of percent cover of *natural area*, *biological artefact area*, *natural surface*, water, sky, buildings, structures and paved/sealed surfaces. The *progress to present-potential cover score* (Chapter 7) was estimated for the first three types of cover. Terms in italics are explained in Box 8.2. Other assessed items were: the naturalness of the water (based on the appearance only); the colour naturalness and reflectivity of buildings, structures and paved/sealed surfaces. Consistent with the *Viewpoint* method the heights of buildings and structures were not assessed since the oblique perspective incorporates the impact of height within the percent cover measurements.

Although the *calculated natural character score* formula includes a hydrological and geomorphological naturalness index (HGNI), it was not expected that participants would be able to identify many of these changes in a short viewing. Accordingly when the *Viewpoint* formula was being applied to the photographs to determine the *calculated natural character scores* only the most obvious hydrological and geomorphological changes were included.

Box 8.2: Special purpose terms used in the QINCCE methodology

Natural areas (NA) have vegetation or benthic cover (including marine encrusting fauna) and are where natural processes predominate. The species are not necessarily native and may include ecological pest plants and/or encrusting fauna.

Natural surface areas (NS) do not have a readily visible biotic cover (e.g. very steep cliffs, highly mobile sands) and are where natural processes predominate.

Biological artefact areas (BAA) are where human management of the biota prevails. This human management is evident in the biological patterns and processes. Biological artefact areas include: agricultural, horticultural and forestry areas, orchards, vineyards, gardens, lawns and other areas of mown grasses.

Present-potential cover (PPC) is the cover that would be present today had humans, their tools and technology, and the introduced species they brought, not arrived in New Zealand and perturbed the environment. It differs from historical vegetation /cover in that it incorporates geological, climatic and other physical changes that have occurred naturally since human arrival as so may not be the "climax" cover for a site (Chapter 7).

Score for progress to present-potential cover (PPCScore) is a score between 0 and 1 that represents the "progress" towards the present-potential cover for different categories of cover within a unit or *Viewpoint*. Scoring tables, compiled for different types of present-potential cover, are used to determine the appropriate PPC Score

Viewpoint method: uses an oblique perspective for assessing parameters and calculating natural character formulae

Calculated natural character score (CNCS) is where the measured and calculated parameter data (obtained using standard plan-view method for a unit, or the *Viewpoint* method for a photograph) is used in the natural character formulae to calculate a natural character score for a unit or a *Viewpoint*.

The parameter data for each photograph were entered into an Excel spreadsheet. All percent cover scores were divided by 100 for use in the natural character formulae. Although all the photographs had been adjusted to minimise the amount of sky, a small amount of sky was included in some photographs. As sky is not included in the natural character formula the adjusted cover of sky was removed from all photographs and the remaining percent cover scores adjusted to total 1. The natural character indices (ENI, HGNI, FBSI and NCI) were then calculated for each photograph with the NCI multiplied by 100 to give the *calculated natural character score* (CNCS) (from 0 to 100). The trimmed mean for perceived natural character score (PNCS) was then directly compared with the CNCS for each photograph.

Initial comparisons between the CNCS and trimmed mean for PNCS showed major discrepancies between the two scores for some photographs. Various options for combining the natural character sub-indices (ENI, HGNI, and FBSI) were tested including differential weighting of some indices. Attempts were made to develop a model that would provide a reasonable match between the CNCS and corresponding trimmed mean PNCS. It was not possible to develop such model(s) that both provided a reasonable match for all 40 photographs in the set and always returned a natural character index (NCI) between 0 and 1. The requirement to always keep the NCI for each photograph between 0 and 1 (multiplied by 100 for the Natural Character Score (NCS) or percent"natural") was to ensure that the methodology would allow data from different types of coastal environment to be aggregated and compared. The 28 terrestrial and 12 marine environment (water-surface) photographs were treated as two separate groups for these analyses.

8.4.6 Refining the formulae for the natural character sub-indices

Given the difficulties with developing a model that met the criteria using the existing formulae for the sub-indices, the next stage was to review these formulae. One change was to remove the percent-native-cover parameter from the ENI, and instead, adjust the scoring system for measuring *progress towards present-potential cover* to consistently address the effects of different introduced species in different coastal environments. This change was needed to remove the "double-counting" of introduced-species-impacts on natural character. The consequence of this double-counting had been that photographs dominated by introduced species (especially pastoral and forestry land uses) but with few building and structure impacts received a very low CNCS. These very low scores could not be adjusted by a weighting on the impact of buildings and structures as there was little "scoring room" available to address any potential additions of building and structure impacts.

Another formula change that arose from the comparison of the trimmed means for PNCS and the CNCS was an adjustment to the scoring system for building and structure colour naturalness within the FBSI. The change was to use the same scoring system for both "colour naturalness" and building and structure reflectivity. This change reduced the "credit" previously given for colour naturalness as this led to too much lowering of building and structure impact scores.

The revised plan-view formulae for the environmental naturalness index (ENI), hydrological and geomorphological naturalness index (HGNI) and freedom from buildings and structures index (FBSI) and the combined natural character index (NCI) are in section 5.5. The *Viewpoint* formulae are similar to the plan-view formulae except that height is not included in the *Viewpoint* buildings and structures impact score (BSIS) because the oblique perspective addresses height as part of the percent area calculations for buildings and structures. It should be noted that the terrestrial ENI formulae (5.5.1) include *Score for freedom from alien mammalian (terrestrial)/ vertebrate (freshwater) species (FAS).* Participants were not expected to have any knowledge about this and so a default score of one was used in the calculated natural character scores. Appendix 10 contains the final calculations for each photograph.

8.4.7 Analysis of participant background information

After several preliminary assessments of the quality and completeness of background information provided by participants, a subset of potential predictor variables (that could affect participant natural character scoring) was selected for further assessment. The qualitative data on the tertiary qualification subject area was used to assign each participant to one of the following qualification categories: environmental sciences, environmental planning/ resource management, landscape architecture, other tertiary qualification and no tertiary qualification. Where a participant had more than one tertiary qualification the subject area of the highest qualification was used.

Qualitative information on organisation type was used to assign each participant to one of the following organisation categories: regional council, district council, Department of Conservation, student (environmental planning) and university (staff and science postgraduate students). The work organisation category was used for participants attending a public meeting in their work capacity. Participants provided categorical data on gender, ethnicity, age group (B=18-30 years, C=31-45 years, D=46-65 years, E=>65 years), and self-reported familiarity with New Zealand mangrove ecosystems (A=none, B=limited, C=moderate and D=high).

Linear Discriminant Analysis (LDA) was used to determine which, if any, of the potential predictor variables (with their groupings) could explain participant scoring patterns. Underlying LDA assumptions (Stat Soft Inc 2010) are:

- The data for the variables represents a sample from a population with a multivariate normal distribution, although some departure from this is permitted. In this case, the "population" is those who are "informed" about New Zealand coastal planning/management/ecology, not the entire New Zealand population.
- The variance/co-variance matrices of the variables are homogeneous across the groups although some variation is permitted
- The means and standard deviations for the variables across the groups are not correlated. If some groups have a few extreme outliers this could have a large impact on the means and increase the variability. The descriptive statistics can be inspected to ensure that there is no correlation between the means and standard deviations
- None of the variables used to discriminate between groups are completely redundant. If any variables are completely redundant with the other variables the matrix is "ill-conditioned"
- The tolerance value (shows the proportion of the variance that is unique to the respective variable) is not zero

The data set is probably sufficiently normal for the population it represents for the purposes of LDA. An analysis of the data (section 8.5.5) shows that the means and standard deviations for the variables across the groups do not generally appear to be directly correlated. It also shows that none of the subset of predictor variables (used for analysis) is completely redundant and the tolerance values are not zero.

8.5 Results and discussion

8.5.1 Perception of natural character in terrestrial environments

Figure 8.1 shows the average perceived natural character score (PNCS) and the 95% confidence intervals for each of the 28 terrestrial photographs. Figure 8.2

provides a comparison between the CNCS and trimmed mean for PNCS for each of the 28 terrestrial photographs. For all except one photograph, the CNCS is lower than the trimmed mean of the PNCS. The photographs are ordered on the basis of the CNCS, beginning with the highest score.

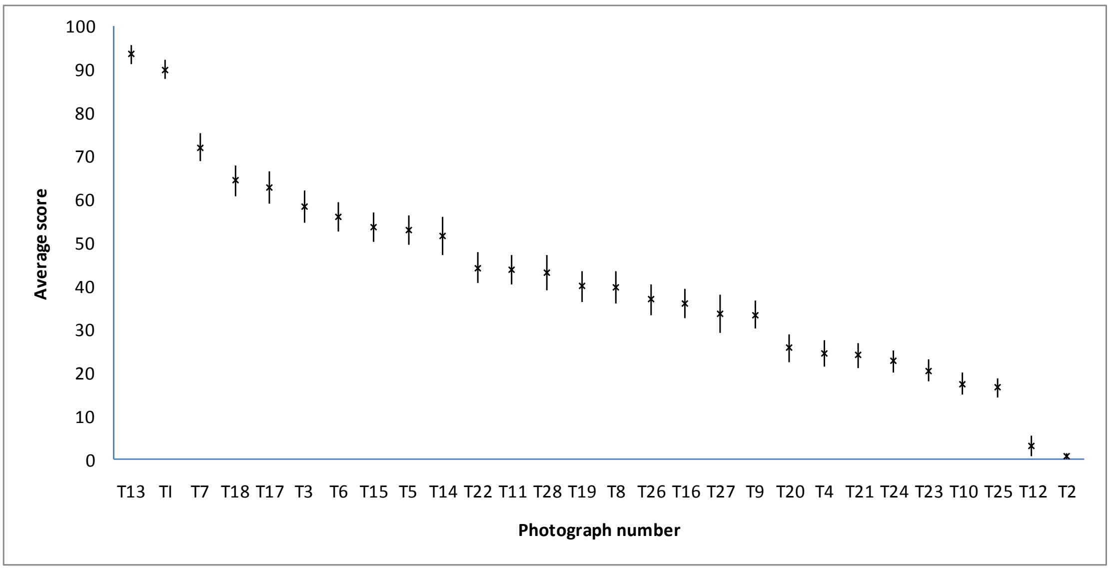

Figure 8.1: Participant natural character scores for the terrestrial photographs. This shows the average PNCS and 95% confidence intervals

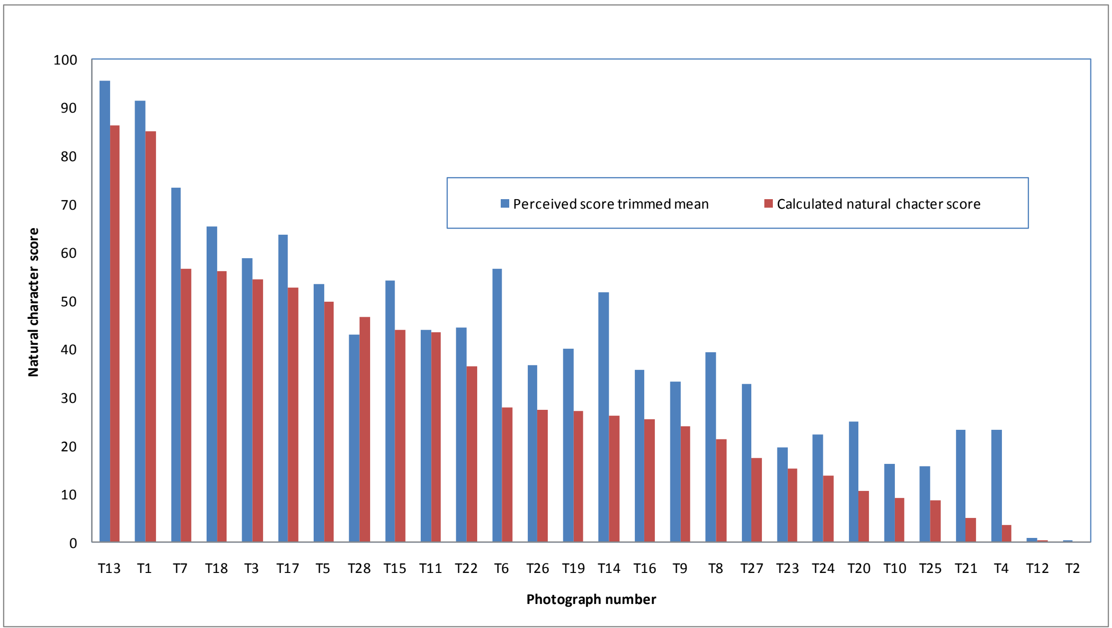

Figure 8.2: Relationship between the trimmed means for perceived natural character score (PNCS) (in blue) and the calculated natural character score (CNCS) (in red) for each terrestrial photograph

Figure 8.3 shows the numerical difference between the CNCS and the trimmed means for the PNCS for each of the 28 terrestrial photographs, while Figure 8.4

shows the ratio between them. In Figure 8.4 the closest match is when the ratio is 1. Appendix 9 contains the photographs numbered in the top left corner.

Those photographs with the highest CNCS are the two positive controls (T13 and T1). These two photographs are free from buildings and structures. T13 is of water and relatively mature coastal forest vegetation for Northland, while T1 contains a classical estuarine vegetation sequence of saltmarsh, mangroves and freshwater wetland (includes the dead leaves of the summer-green rede –raupo (*Typha orientalis*) to native forest in the background. These are followed by a group of photographs where only a small proportion is occupied by a building or structure and the rest of the image is generally native vegetation with natural surface shoreline and sometimes water. A minor exception is photograph T3 which does include an area of pasture in the background but the foreground contains natural surface, water and native vegetation.

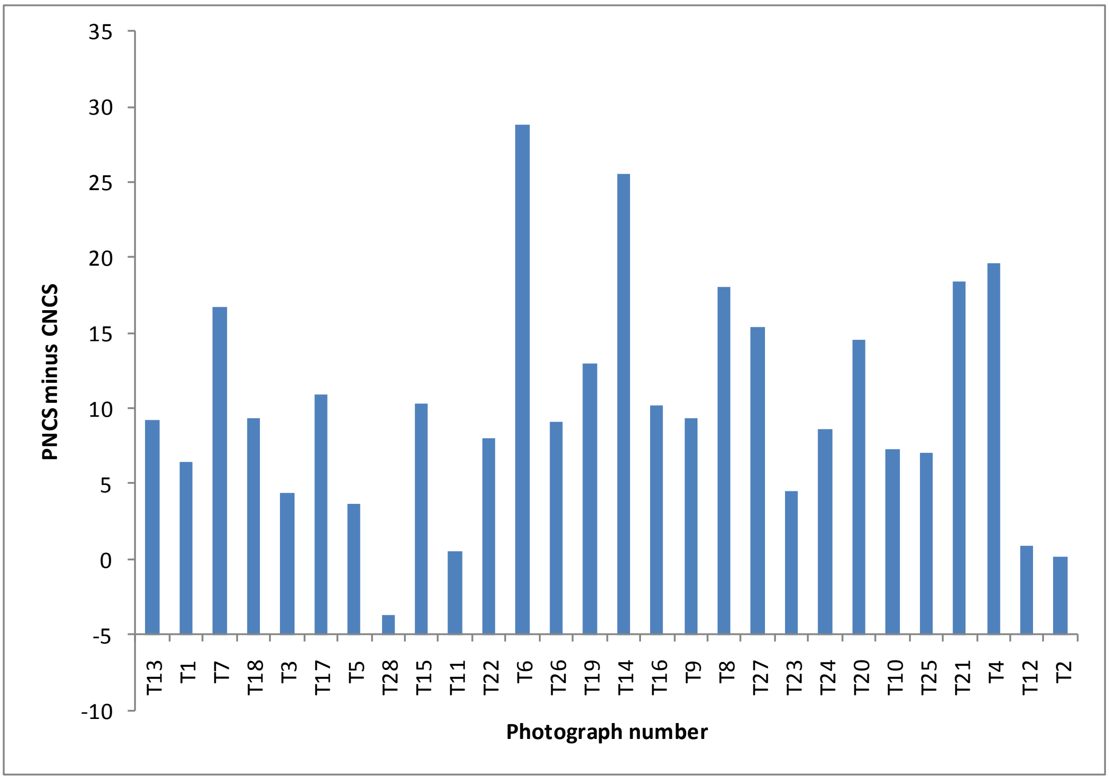

Figure 8.3: Natural character scores for the terrestrial photographs. This shows the perceived natural character score (PNCS) minus the calculated natural character score (CNCS). The photographs ranked from high to low for CNCS

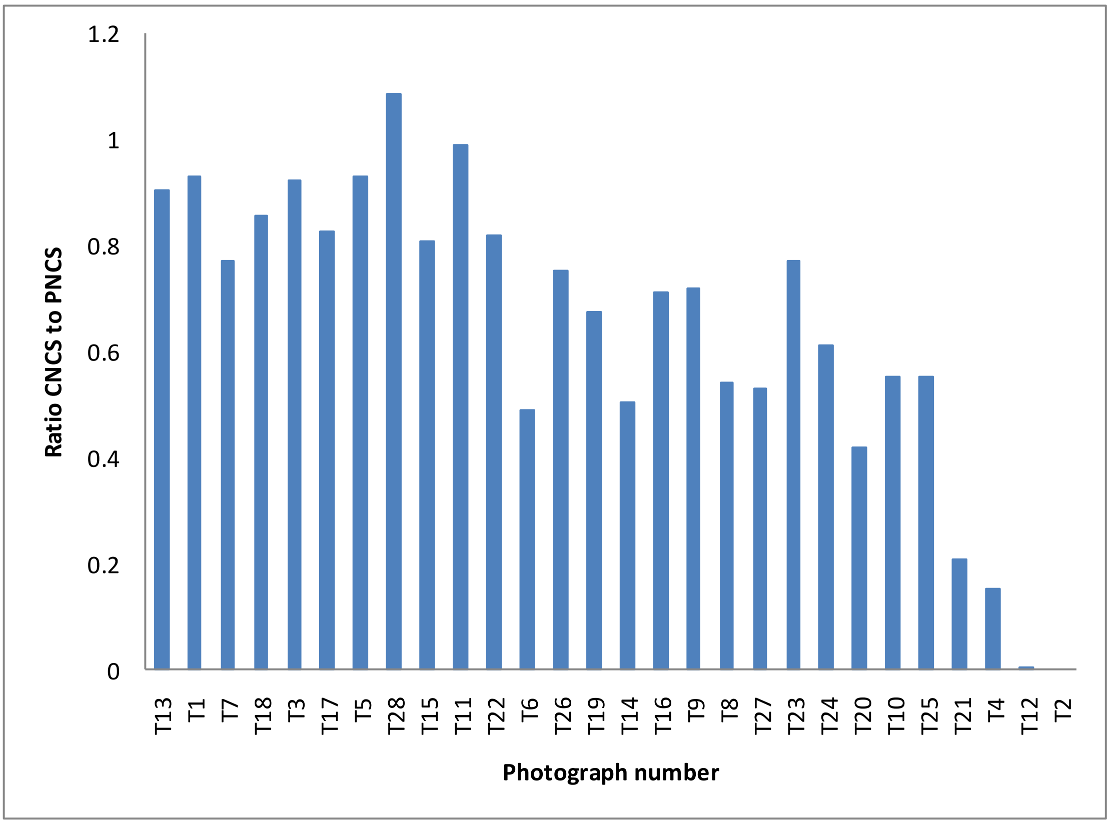

Figure 8.4: Natural character scores for terrestrial photographs. This shows the ratio of the calculated natural character score (CNCS) to perceived natural character score (PNCS). The photographs are ranked from high to low for CNCS

The two terrestrial photographs with the lowest CNCS are the negative controls (T2 and T12). These two photographs have no natural elements (sky was expressly excluded from the assessment) and have industrial structures, large buildings and paved areas. One of these negative controls is of the Ports of Auckland working area and the other is of downtown Auckland from the Viaduct Basin. T4 is the next lowest scoring terrestrial photograph. It contains a house, seawall and ramp in the foreground with pasture and a small area of kanuka scrub in the background. This is followed by photograph T21 where the foreground is paved, there a marine farming building with equipment and debris behind, and a limited area of low mangroves in the background.

The ratio of the CNCS and trimmed mean of the PNCS for each photograph shows how closely the scores match. The two scores are close for those photographs which have ratios between 0.8 and 1.2 (the positive controls (T13 and T1), T18, T5, T3, T17, T28, T15, T11, and T22). All except the last three are also in the group of photographs with the highest calculated scores. The CNCS and trimmed means for the PNCS for the negative controls (T2, T12) are both at or close to zero and so the ratio becomes zero. The actual differences between the calculated and perceived scores for the negative controls are very close to zero.

There is a group of photographs where the difference between the CNCS and PNCS is much larger. The ratio between the CNCS and trimmed means for PNCS is below 0.5 for photographs T6, T14, T20; and below 0.2 for photographs T4 and T21. These photographs are characterised by a developed foreground and a much more natural background. In all except one case the foreground is occupied by buildings. The methodology for determining the CNCS uses a grid over a photographic image for estimates of percentage cover. Where a large amount of the foreground in a photograph is occupied by buildings and other development this substantially reduces the CNCS. It is possible that participants made a mental adjustment that because the more natural background represented a larger area on the ground they gave an increased weighting to this background. This would have resulted in a higher PNCS. It is also possible that the focus of participants was drawn to the more natural area as it was in the upper part of the photograph. In contrast, the CNCS and the trimmed means for the PNCS were more similar for photographs where the foreground was relatively natural, and any development was away from the foreground. Section 8.7.4 contains suggestions for addressing possible differences in PNCS due to different viewing perspectives.

Pasture was part of several photographs where there were differences between the CNCS and trimmed means of the PNCS. It is possible that at least some participants scored introduced pasture grasses as more natural than the calculated scores which used clearly specified scoring protocols. This is particularly likely for photograph T14 where the foreground is mown kikuyu grass in a largely empty coastal campground. Kikuyu grass hinders native regeneration in many northern coastal locations but because it remains green and vigorous it can be perceived as more ‘natural’ than some other pasture grasses. As the original focus of this perception study had been to determine the relative weighting between the freedom from buildings and structures index (FBSI) and the ecological naturalness index (ENI), photographs of pastoral scenes without structures were not included as controls.

The CNCS was (slightly) higher than the trimmed means for PNCS only in photograph T28. The foreground in this photograph is dominated by the native sand-binder spinifex (*Spinifex hirsutus*) on sand. It is likely that some participants did not recognise the native sand binder in the context of the introduced pasture grasses further inland and so they scored the photograph as if the foreground was dominated by introduced grasses.

It is possible that the trimmed means of the PNCS for the terrestrial photographs are typically higher (not always by much) than the CNCS because there has been a shift in the perceived natural character baseline. This "shifting baselines" phenomenon has been widely discussed for marine environments (Pauly 1995; Jackson 2001; Pinnegar & Engelhard 2008b; Parsons et al. 2009; Taylor et al. 2011 in prep). In summary, each generation considers the situation prevailing when they began their marine activities as the "naturalness baseline" and so do not adequately acknowledge the extensive degradation that had occurred before that time. This is particularly relevant to the structure and composition of *natural areas*. In some northern New Zealand terrestrial coastal environments, natural regeneration on abandoned farmland (e.g. parts of the Bay of Islands with poor-quality soils) has increased the ecological naturalness of those areas compared to 30-50 years ago. However, the almost complete removal of the original coastal forest that dominated northern coastal environments (outside of areas of mobile dunes and impeded drainage) has probably led most people to use a relatively modified natural character baseline, especially for the open coast.

8.5.2 Perception of natural character in marine environments

Figure 8.5 contains the average PNCS and the 95% confidence intervals for each of the 12 topside (water surface) marine environment photographs. Figure 8.6 contains a comparison between the CNCS and the trimmed means for the PNCS for each of these photographs. The photographs are ordered on the basis of the CNCS, beginning with the photograph with the highest score. Figure 8.7 shows the numerical difference between the CNCS and the trimmed means for the PNCS for each of the marine photographs, while Figure 8.8 shows the ratio between these scores.

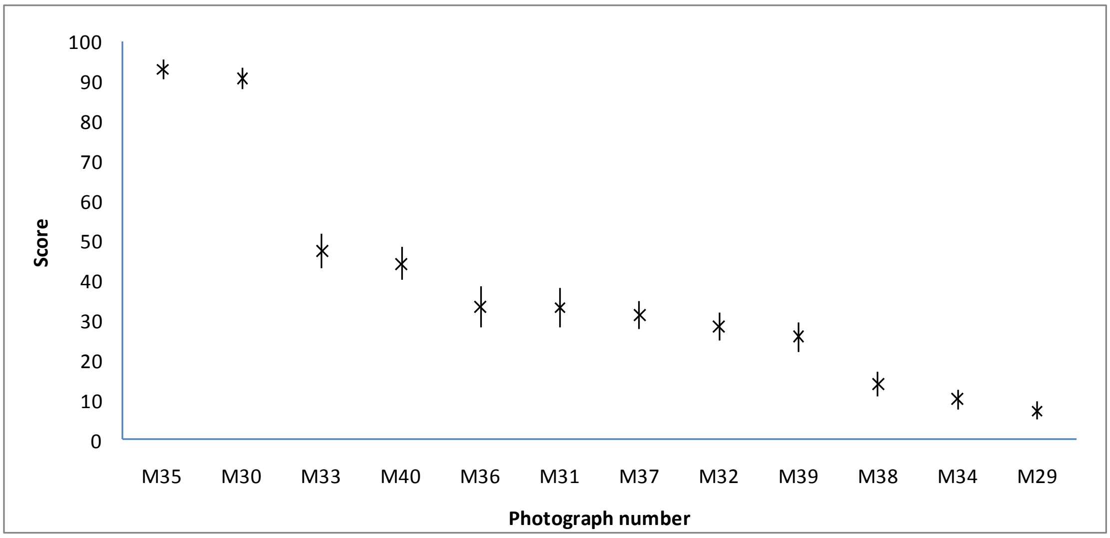

Figure 8.5: Participant natural character scores for the marine environment water-surface photographs. This shows the average perceived natural character score (PNCS) and the associated 95% confidence intervals

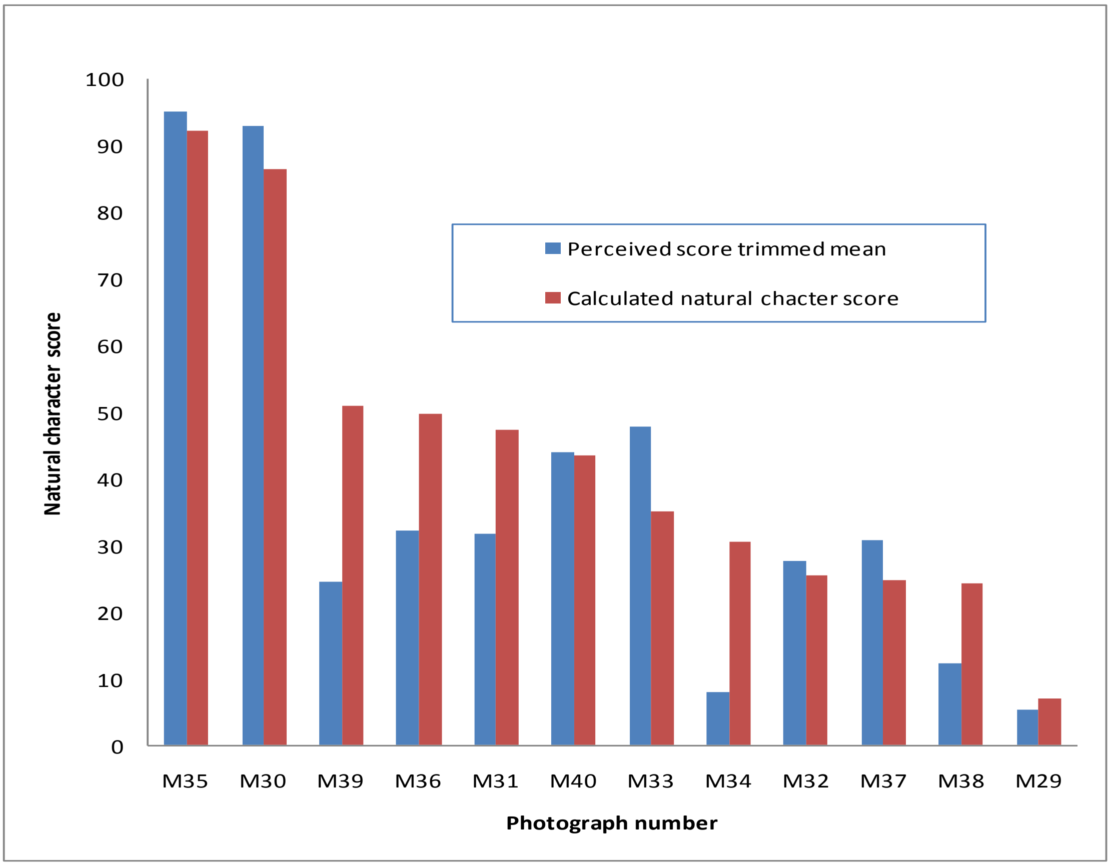

Figure 8.6: Relationship between the trimmed means for perceived natural character scores (PNCS) and the calculated natural character scores (CNCS) for each photograph of the marine environment water- surface

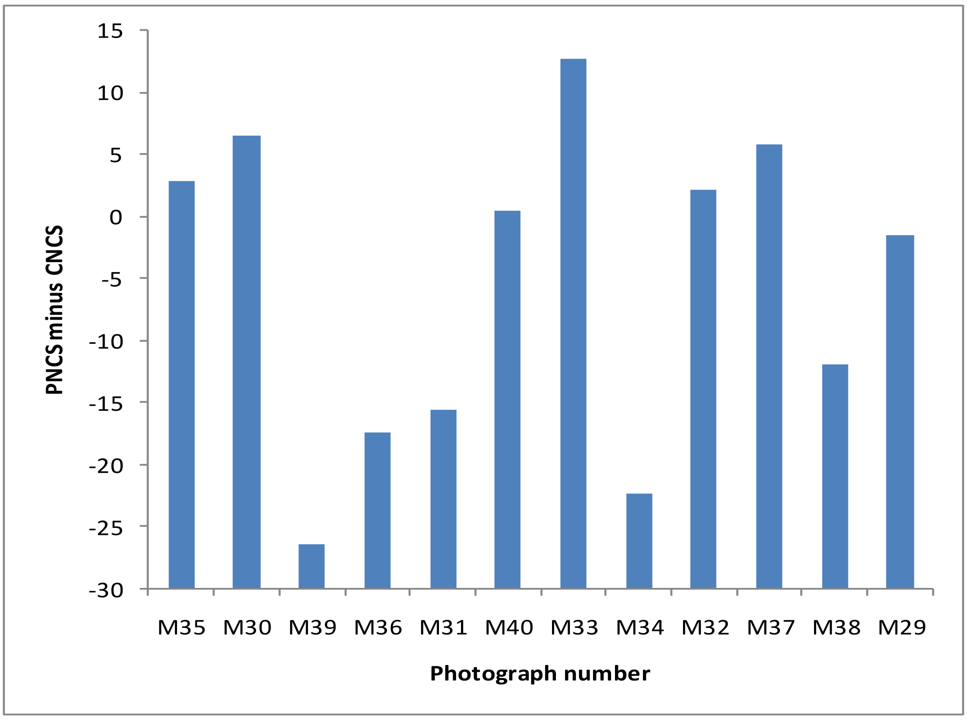

Figure 8.7: Natural character scores for the marine environment water-surface photographs. This shows perceived natural character scores (PNCS) minus the calculated natural character scores (CNCS). The photographs are ranked from high to low for CNCS

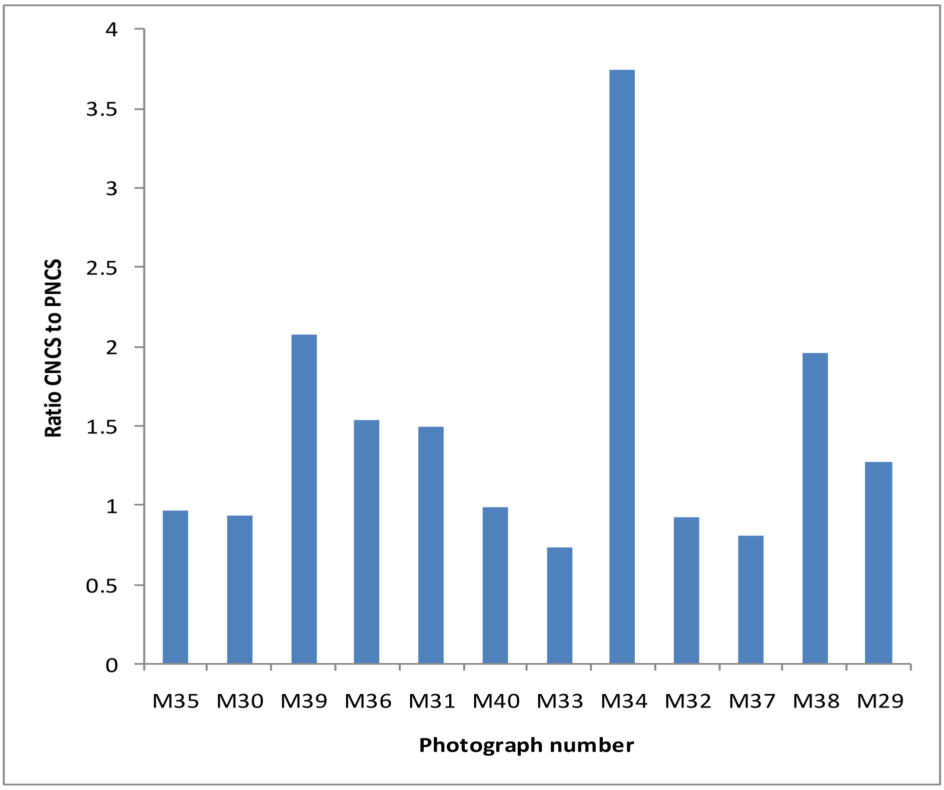

Figure 8.8: Natural character scores for the marine environment water surface photographs. This shows the ratio of calculated natural character score (CNCS) to perceived natural character score (PNCS). The photographs ranked from high to low for CNCS

The relationship between the CNCS and the trimmed means for the PNCS for the marine water surface varies between photographs, especially in comparison to the terrestrial environment. If the marine environment photographs are divided into two groups the relationship becomes more consistent. The first group of photographs includes a significant portion of land whose characteristics are readily identifiable. This group includes the two positive controls (M35 and M30), M40, M32, M33 and M37. For these photographs, the ratio between the CNCS (using the same approach as for the terrestrial photographs) and the trimmed means for PNCS is close to 1 and slightly positive. Evidence to date suggests that no formulae adjustments will be needed for any of the natural character indices for water surface marine environments when the characteristics of the land are clearly visible. This applies to both the *Viewpoint* and the plan view perspectives.

In the second group of topside marine environment photographs, there is either no land, or if there is land it is very limited in extent, distant relative to the viewpoint and its attributes may be unclear. This group includes photographs M31, M34, M36 and M38. For these photographs the CNCS are greater than the trimmed means of the PNCS and the ratio between them is greater than 1.5. One further photograph without land is the negative control (M29). This photograph has the lowest CNCS, but has a CNCS to trimmed mean of the PNCS ratio of 1.27.

Water occupies a large amount of space in this second group of photographs with the rest largely being structures. The attitude people have towards a water-body is affected by the condition of the water and the surrounding land (Coughlin 1976). In an assessment of how people perceived water clarity and colour in relation to the suitability of the water-body for bathing, Smith et al. (1995b) found that where a water body and the state of its water was perceived as natural this increased the visual rating of the water body above what might have been expected. The converse may also apply. If the primary context that water is seen in is that of human structures, then the perceived visual rating of the water may decrease. This could mean that people perceive the water to be less natural than it actually is. If this has occurred it may be an example of "perceptual set" which is the readiness to perceive a stimulus in a particular way (Anonymous 1975). In other words we tend to perceive what we expect to see (Smith et al. 1995b).

The colour of the water in the marine environment photographs is relevant in an assessment of how those images with a considerable amount of water have been scored. Smith et al. (1995a) found that people generally preferred blue waters for bathing, but yellow coloured water was acceptable if it is perceived as “natural”. Different stimuli affect perceived water quality which may be different to the actual or intrinsic water colour. Light reflected from the surface gives an observer a distorted image of sky, clouds, surroundings and the sun (Smith et al. 1995a). Actual water colour is associated with light reaching the observer via backscattering and multiple forward-scattering. In shallow waters reflections from the substrate and aquatic vegetation can also affect the signal received by the eye (Smith et al. 1995a). The perceived water hue (colour) as seen in the marine environment photographs varies. Where there is adjacent land to provide context, the naturalness of the water has probably been assessed in that context. In those photographs where there is no land or it is far away, it is the structure that provides the context. Photographs M34, M36 and M38 all appear to have blue or blue-green water but this has not necessarily influenced their scores because the structures are very dominant. As an aside, the usual colour of the water depicted in M38 is a yellow-green.

Photograph M39 did not fit either of the two previously described categories of marine environment photographs. This photograph depicts a telephoto view of training walls leading into a marina (not visible in the photograph) with a part of a vegetated cliff and a road along the base of the cliff. There is a considerable amount of water in the foreground. The perspective used in this photograph is unusual, given the focus on the training wall and water in the foreground, and is likely to have confused participants. This probably contributed to the two fold difference between CNCS and the trimmed means for PNCS. Given the unusual perspective of this photograph it is proposed that it be treated as an exception and not be used for determining how the two types of situation be treated in the natural character formula.

8.5.3 Amendments to the natural character formulae for the marine environment

The differences between the CNCS and the trimmed means for PNCS for the second group of photographs suggests that the formula used for calculating the NCI be amended when either there is little or no clearly visible land in a *Viewpoin*t or within a water-surface plan-view unit. Although there was some model development work, the size of the photograph set was not sufficiently large to develop a reliable model. An indicative starting position could be to double the BSIS for *Viewpoints* with little or no land and for plan-view units containing only water surface. Further adjustment may be needed to ensure that the NCI lies between 0 and 1.

8.5.4 Methodology lessons and questions for future investigation

Overall the methodology used to determine the perceptions of informed participants about the levels of natural character present in different situations worked well. Most participants found the exercise interesting and enjoyed participating. The number of photographs used seemed appropriate for the participants. There were, however, some aspects of the design and implementation of the methodology that could have been improved.

The first would be to use a consistent and familiar perspective for the photographs. Some of the differences between CNCS and the PNCS may have been caused by the unusual perspectives used for some photographs (e.g. M39). During discussions at some organisations after the completion of the scoring exercise, some participants explained that they had found it difficult to score natural character levels for some photographs. One problem raised was the use of different perspectives- close and medium distance; and in one case the view from a low hill rather than the more typical ground level perspective. Although most photographs did use a similar perspective, it is recommended that future studies of this type should remove potential distractions by using a standard perspective for all photographs.

The photograph set was compiled to test how people weighted the impact of buildings and structures relative to ecological naturalness. While the scenes with buildings and other structures were variable, the limited number of controls did not address all circumstances. This complicated the interpretation of the PNCS for some photographs. For example, the lack of a pasture control meant that it was difficult to determine the contribution of the building or other structure to the perceived scores for pasture dominated photographs. Future studies of this type should use a "non-impact" control for the major types of circumstances addressed by the "impact" photographs.

Some of the compromises made, especially the scope of the control photographs, were because many different situations were being assessed. The study was designed to assess the impacts of buildings and other structures in a wide range of circumstances, to ensure that the formula being developed would be widely applicable. While a solution would be to include more photographs, participants can become weary if there are too many photographs.

Computer software (e.g. Photoshop) could have been used to manipulate photographs to create 'with' and 'without' impact pairs. This would have given a more robust approach for determining how people weigh the impacts of buildings and other structures in different circumstances. For example, several buildings could be added to a scene without buildings or other structures, and both photographs included randomly within the photograph set. If this approach (or the alternative of removing buildings and structures) was used, this would allow direct comparison of the perceived scores between photographs 'with' and 'without' buildings and structures. For this to be convincing the quality of the photo manipulation would need to be very high.

Another component of the study that may have improved the robustness of the results would have been to be more specific at the outset as to what constituted an "informed participant". A relatively large number of participants was sought so as to obtain a sufficiently large sample for statistical analysis purposes. As a consequence not all participants were "well informed". This probably explains some of the variability with participant PNCS. This was addressed, at least in part, by using trimmed means in the analyses. As this purpose of this perception research was to improve the QINCCE methodology, rather than evaluate general public perceptions on natural character a smaller, more targeted group of participants (as used by Taylor et al. in prep (2011 in prep) may have been appropriate.

The perception assessment did not include the subtidal environment. The use of photographs to assess subtidal natural character is problematic and I was unable to find any literature where researchers had sought to do this. As an alternative, Taylor et al.(2011 in prep) asked long-term divers to use only their memory and dive logs to recollect changes over four time periods (beginning with pre-1971) in the relative abundances of particular species and ecological communities in the waters of the current Poor Knights Marine Reserve (New Zealand). A comparison of diver recollections with the far more limited (in terms of the span of time covered) monitoring data found that the divers were not inconsistent with the monitoring data and that recent improvements following the establishment of the full marine reserve were relatively small compared to past declines. The authors noted that most of the participating divers had a good knowledge of marine life.

There are practical problems associated with obtaining appropriate photographs to assess perceptions of naturalness for subtidal seascapes. Matters that need to be addressed include lighting (for low light environments), poor water clarity (especially in harbours and estuaries) and the confounding effects of short-term storm damage. The impact of structures in the subtidal marine environment is generally more subtle than on land as subtidal structures often act as substrate for encrusting organisms. Other human activities can have profound impacts on marine naturalness but these can be difficult to determine from a photograph without contextual information. It is likely that alternative approaches to those used in this assessment would be needed to assess human perceptions of subtidal naturalness. As less experienced divers tend to be more satisfied with a lower level of naturalness (Richard Taylor, University of Auckland pers. comm.), it would be necessary to use a more limited population of “well-informed” participants.

8.5.5 Participant characteristics and potential impacts on perception scores

Figures 8.9, 8.10 and 8.11 show the numbers of participants with different combinations of participant attributes. Table 8.2 summarises the category codes used in these figures. The figures show different numbers in each participant grouping and so should be interpreted cautiously.

Table 8.2: Participant attribute codes used in Figures 8.9-8.11

Participant attribute	Codes	Definition
Tertiary qualification subject	Scienv	Environmental science
	Envplan	Environmental planning
	La	Landscape architecture
	Other	Other tertiary qualification
	None	No tertiary qualification
Organisation	Districtc	District council employee
	Regionalc	Regional council employee
	NDOC	Department of Conservation, Northland conservancy employee
	Public	Member of/attendee AGM of Bay of Islands Maritime Park Inc and/or Guardians Bay of Islands Inc
	Student	3rd year Undergraduate environmental planning Lincoln University or postgraduate environmental planning student Waikato University
	Uni	Waikato University Science Faculty, staff member or postgraduate student
Age class	B	18-30 years
	C	31-45 years
	D	46-65 years
	E	>65 years
Self-reported familiarity with mangroves	A	None
	B	Limited
	C	Moderate
	D	High

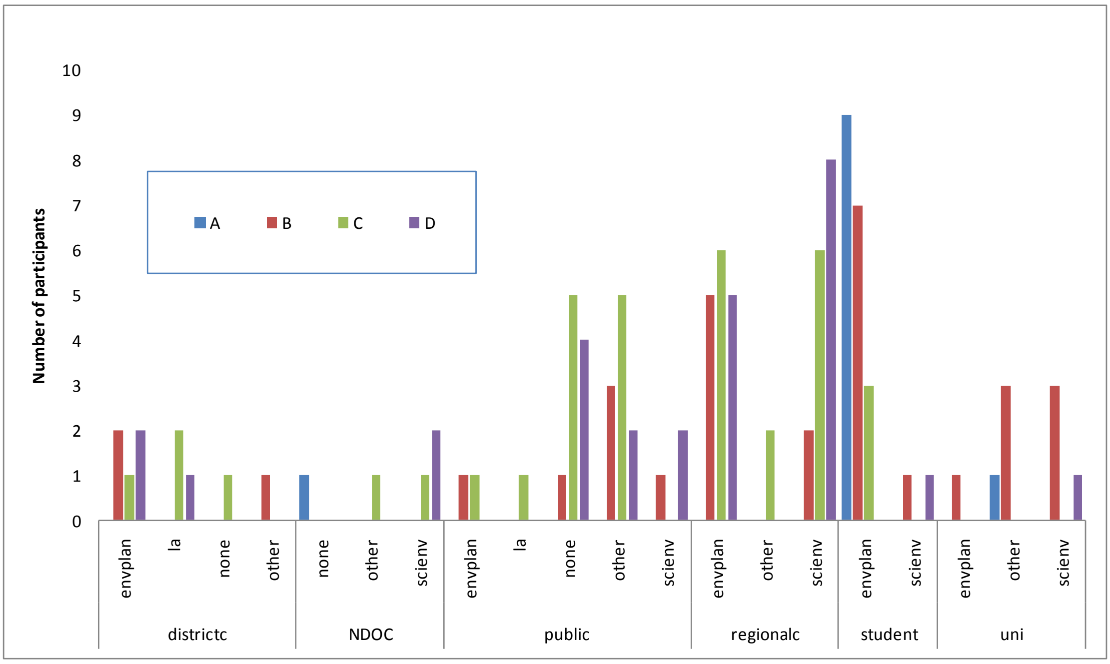

Figure 8.9: Categorization of participants in the perception study: This shows the number of participants when they are separated on the basis of organisation (district council, Department of Conservation, public, regional council, university planning student, university science staff), qualification (environmental science, environmental planning, landscape architecture, other tertiary qualification, no tertiary qualification) and self-reported familiarity with mangroves (A-none, B-limited, C-moderate, D-high)

In Figure 8.9 the numbers of those reporting no or low levels of knowledge about New Zealand mangrove communities was proportionally highest for the university student participants, especially those with environmental planning/ resource management qualifications. Those with the highest self-reported levels of knowledge of New Zealand mangroves were regional council participants with environmental science qualifications, followed by those with environmental planning/ resource management qualifications. Most participants from Bay of Islands public interest groups reported a moderate knowledge of New Zealand mangroves.

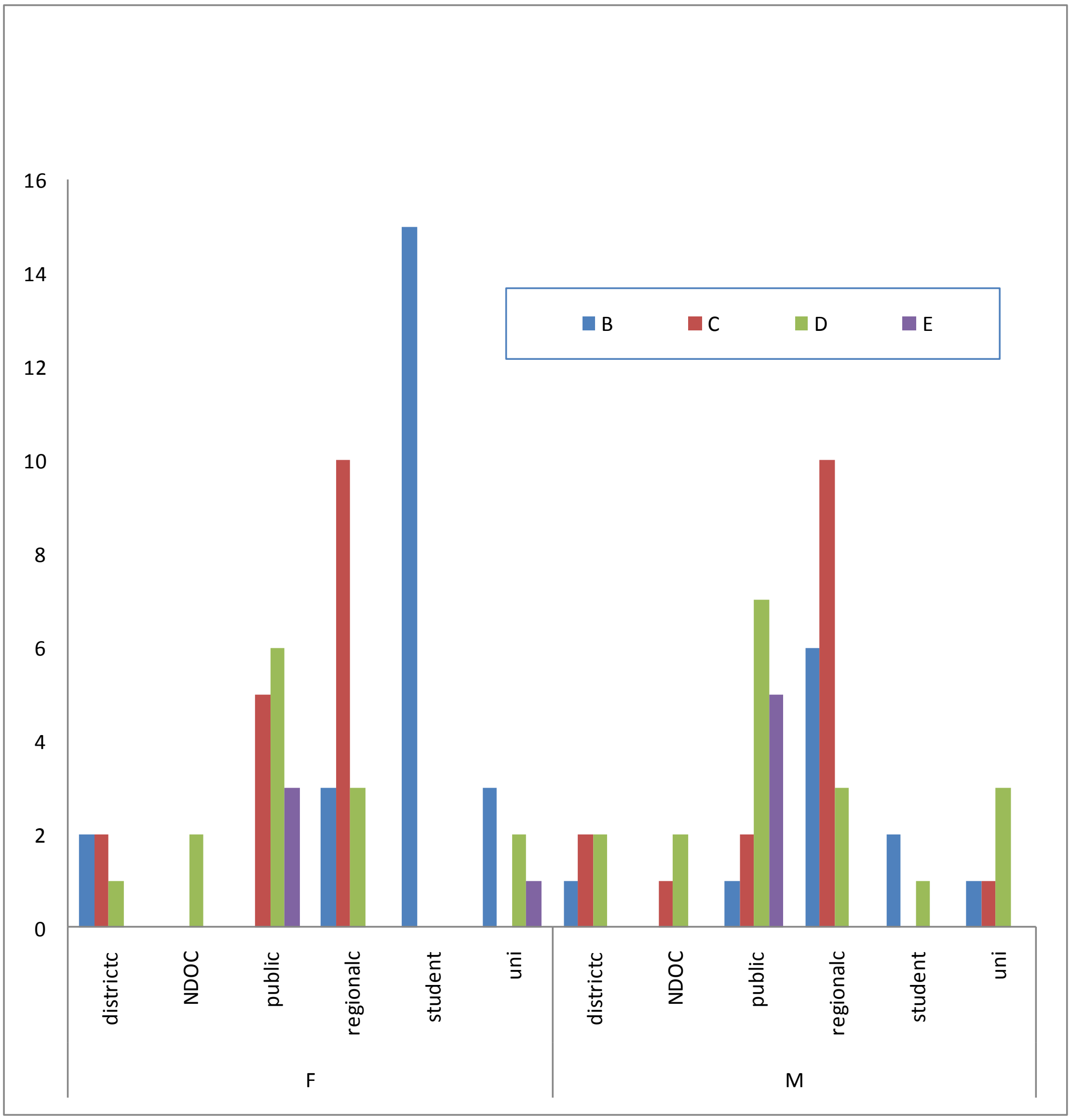

Figure 8.10: Categorization of participants in the perception study. This shows the number of participants when they are separated on the basis of gender, organisation (district council, Department of Conservation, public, regional council, university planning student, university science staff), and age group (B=18-30 years; C=31-45 years; D=46-65 years; E>65 years)

Figure 8.10 shows that the oldest age-category (>65 years) was concentrated in the Bay of Islands public interest groups which is unsurprising given the standard New Zealand retiring age of 65. The bulk of regional council participants were in the 31-45 years age-category. Female members of the Bay of Islands public interest groups were the next largest block in this age category. The majority of the Bay of Islands public interest group participants were in the 46-65 years age-category. This was also the most common age category for the university science faculty members and Department of Conservation participants.

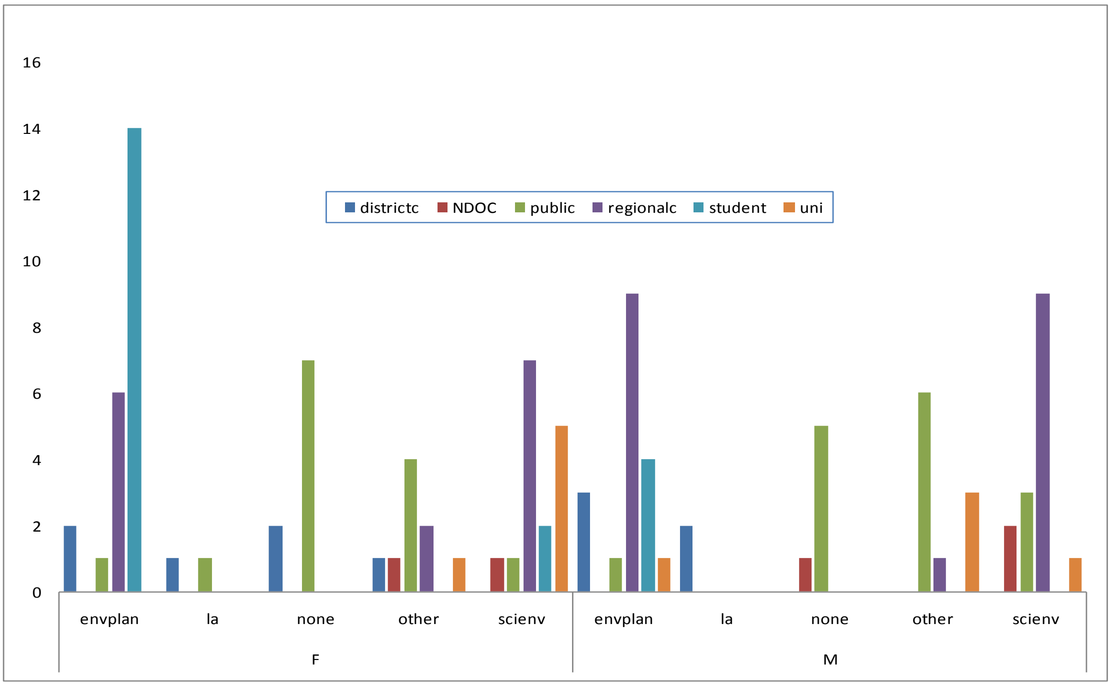

Figure 8.11: Categorisation of participants in the perception study: This shows numbers of participants when they are separated on the basis of gender, qualification (environmental science, environmental planning, landscape architecture, other tertiary qualification, no tertiary qualification) and organisation (district council, Department of Conservation, public, regional council, university planning student, university science staff),

Figure 8.11 shows the numbers of participants separated by organisation category, tertiary qualification category and gender. It shows that the majority of those in the Bay of Islands public interest groups either have no tertiary qualifications or have different qualifications to those specifically identified in the graph. The regional council participants primarily had environmental planning/ resource management and environmental science qualifications. The majority of participants with environmental science qualifications were regional council participants. While the majority of the male participants with environmental planning/ resource management qualifications were regional council employees, the majority of the females with those qualifications were students.

Linear discriminant analysis (LDA) was used to investigate whether particular participant attributes may have affected their scoring of natural character levels, at least for some photographs. It was only possible to assess five predictor variables at a time and so after several trials the following predictor variables (participant attributes) were selected: gender, age category, organisation, tertiary qualification subject and self-reported familiarity with mangroves. Wilk lambda can be used to test the null hypothesis that all the groups or categories within a predictor variable (e.g. age-category) are identical. Where Wilks lambda is small (close to 0) it means that the groups are well separated, whereas a large Wilks lambda (close to 1) means that the groups are poorly separated.

Table 8.3 indicates that there was an overall difference between groups or categories for the predictor variables of: gender, organisation, age- categoryand self-reported familiarity with New Zealand mangroves. Wilks' lambda is nearest zero (perfect discrimination) for the predictor variable "organisation category". This implies that differences in participant natural character scoring were greatest when participants were sorted according to the organisation they worked for or were affiliated with. The Wilks' lambda is largest for gender at 0.5, implying that the difference between males and females was not large, but given that the p-value was less than .05 there is a probability of at least 95% that this difference is significant.

The p-value is below 0.05 for all predictor variables in Table 8.3 except tertiary qualification subject category. This implies that there is at least a 95% probability that there is an overall difference between the classes or categories used for all the predictor variables except for tertiary qualification subject area.

Table 8.3: Summary of the overall linear discriminant analysis for each predictor variable (specified participant attributes) for the participants who took part in the natural character assessment exercise

Predictor variable	Wilks lambda	P value	Overall difference	Photographs where difference indicated
Gender	.500	.0356	Yes	T2,T3, T8, T9, T22
Tertiary qualification	.12	.1659	No	T21, T28
Organisation	.047	.0066	Yes	T11, T21, T26
Age category	.143	.0120	Yes	T17, M35, M38
Familiarity with New Zealand mangroves	.121	.0081	Yes	T1,T3, T11, T23, M34

Table 8.4 presents the analysis for those photographs identified through Statistica LDA as ones where the organisation-category appeared to make a difference for participant scoring (p-level <0.05). T11 is a negative control and some of the difference may have been because some students scored this well above 0 (possibly because of the sky even though participants had been told to ignore the

sky in their scoring). T21 depicts an oyster farming building, equipment and debris with mangroves in the background. The ratio between the CNCS and trimmed means for PNCS for this photograph was 0.2 making it the second to poorest match for the assessed photgraphs. Photograph T26 shows sand and the introduced kikuyu grass in the foreground, with several houses and native scrub and forest in the top third.

The Squared Mahalanbois Distance is used to show the distances or ammount of difference between the groups or categories for a predictor variable. Table 8.5 shows Squared Mahalanbois Distance between the groups for the organisation predictor variable. This table shows the largest differences were between Department of Conservation staff versus university planning students, university science faculty members and district council staff (planning and parks/reserves). There was a large distance between University science staff versus district council staff, and a large but lesser distance between Bay of Islands' public interest groups and regional council staff. Some of these distances should be treated with caution as the Department of Conservation group contained only five participants.

Table 8.4: Photographs where linear discriminant analysis shows that participant organisation appears to affect particiapant perceived natural character scores

Photograph number	Wilks Lambda	Partial Lambda	F remove 5, 64	P level	Tolerance	1-tolerance
T11	0.060	0.799	3.222	0.012	0.203	0.797
T21	0.059	0.812	2.967	0.018	0.362	0.638
T26	0.058	0.827	2.670	0.023	0.226	0.774

Table 8.5: Linear discriminant analysis Squared Mahalanobis Distance for predictor variable participant organisation showing the magnitude of difference between the organisation groups

Organisation	Student	Public	Northland DOC	District council	Regional council	University staff
Student	0	7.458	18.444	15.7222	7.814	12.658
Public	7.458	0	11.581	13.098	5.799	16.285
Northland DOC	18.444	11.581	0	24.707	11.461	28.255
District council	15.722	13.098	24.707	0	9.262	21.726
Regional council	7.814	5.799	11.461	9.262	0	15.872
University staff	12.658	16.285	28.255	21.726	15.872	0

Table 8.6 identifies those photographs where age-category appeared to make a difference for participant scoring (p-level <0.05). Photograph T17 shows glimpses of structures and gardens hidden behind mature coastal pohutukawa trees. Photograph M35 is a positive control for the marine environment and illustrates a foredune with the native sand-binder spinifex and the sea beyond. This photograph had the largest tolerance score in this set. The age-category variable is 53% redundant compared to other variables in this case. The tolerance was lower, and therefore the redundancy was higher, for the other photographs. M38 shows a marina and building.

Table 8.7 contains the Squared Mahalanbois Distance for the age categories. The largest distances are between age-group E (>65) versus all other age-groups, especially D (46-65) and C (31-45). Participants from this older age group were almost exclusively all from Bay of Islands' public interest groups and were probably retired whereas the other age groups were split across all organisation groupings.

Table 8.6: Photographs where linear discriminant analysis shows that participant age-group appears to affect the perceived natural character scores of the participants

Photograph number	Wilks Lambda	Partial Lambda	F remove 3,63	P level	Tolerance	1-tolerance
T17	0.163	0.881	2.833	0.045	0.239	0.761
M35	0.179	0.800	5.248	0.003	0.465	0.535
M38	0.164	0.871	3.098	0.033	0.180	0.820

Table 8.7: Linear discriminant analysis Squared Mahalanobois distance where the participant's age group is the predictor variable

Age group	B (18-30)	D (46-65)	E (>65)	C (31-45)
B	0	6.601	11.975	5.767
D	6.601	0	14.670	5.107
E	11.975	14.670	0	13.343
C	5.767	5.107	13.343	0

Table 8.8 identifies those photographs where self-reported familiarity with mangroves appeared to make a difference to participant scoring (p-level <0.05). Photograph T1 is a positive control that includes saltmarsh, mangroves and native forest in the background. This photograph has the largest tolerance score for this variable. Interestingly, self-reported knowledge about mangroves did not seem to

affect scoring for other photographs containing a significant amount of mangroves, regardless of whether they were intact (T5) or clearly damaged (T6, M33). There were a few small mangroves on the rocks in T23 but it seems unlikely that this would have greatly affected scoring. Photographs T3, T11 and M34 do not include mangroves. M34 is a negative control for the marine environment. The largest Mahalanobis distances (Table 8.9) are between those who reported no-knowledge of mangroves versus everyone else.

Table 8.8: Photographs where LDA shows that participant self-reported familiarity with mangroves appears to affect PNCS

Photograph number	Wilks Lambda	Partial Lambda	F remove 3,58	P level	Tolerance	1-Tolerance
T1	0.149	0.815	4.378	0.008	0.412	0.588
T3	0.140	0.866	3.003	0.0377	0.292	0.708
T11	0.143	0.845	5.550	0.0198	0.181	0.819
T23	0.140	0.863	3.056	0.035	0.190	0.810
M34	0.144	0.838	3.732	0.016	0.172	0.828

Table 8.9: Squared Mahalanobois distance where the participant's self-reported familiarity with mangroves is the predictor variable

Self-reported familiarity with mangroves	A (none)	C (moderate)	B (low)	D (high)
A	0	11.760	15.284	10.715
C	11.760	0	7.081	5.037
B	15.760	7.081	0	8.228
D	10.715	5.037	8.228	0

8.5.6 Commentary on methodology used to assess participant attributes

Consideration was given as to whether the perceived scores should be standardised by some type of transformation. Daniel and Boster (1976) describe how the scoring strategies of different participants can be standardised by using a transformation based on each participant's mean and standard deviation. One reported benefit of this approach was to facilitate comparisons where different interval scales have been used. The current study used 101 point scale (0-100) in contrast to the 10 or fewer interval scales discussed by Daniel and Boster (1976). In addition, methods encouraged participants to use the entire 101 point scale (e.g. inclusion of controls for either end of the scale, showing the full set of images before scoring). While there was variation in how participants applied the 0-100 scoring scale, most participants did spread their scores across the scale.

There are good reasons not to standardise the data. Inappropriate standardisation can indicate perception differences when the differences are variations in the use of the rating scale, and true differences in observer reactions can be obscured by transformation (Daniel & Boster 1976).

Discriminant Function Analysis is an appropriate statistical technique for examining a set of independent predictor variables in order to explain a non-metric dependent variable. This approach is reasonably robust with respect to departures from the method's assumptions (Anonymous 2010). Suggested improvements include: increasing the size of some organisation groupings (e.g. more Department of Conservation staff); removing the category of landscape architect from the tertiary qualification subject groupings as there were too few participants with this qualification.

The breadth and variation in the photograph set limited the explanatory powers of the analysis used. A more systematic and more tightly constrained set of photographs may provide more explanatory power. A very tightly constrained set of images may, however, be limited in its applicability.

8.6 Conclusion

The overall purposes of this perception research were to assist with: determining the relationships between the three sub-indices in the NCI; and refining the parameter set (and parameter scoring regimes) used for each sub-index. Following intensive analysis of the CNCS and PNCS data, the parameter set and scoring ranges and protocols were refined for terrestrial and intertidal environments and the water surface. The primary changes to the ENI were to remove the *% native cover* parameter and to adjust the scoring tables for the *progress towards present-potential cover* parameter to more systematically address the impacts of different introduced species. The scoring tables for several parameters used to determine the Building and Structure Impact Score BSIS (used in the FBSI) were also amended. After considerable testing it was decided that the three sub-indices would be multiplied together without weightings for the overall natural character index. It was proposed that a weighting be added to the BSIS (or parameters that contribute to that score) for water surface units and *Viewpoints* with little or no proximal land. In facilitating these methodology refinements, the perception research has addressed its overall purposes.

The secondary purpose was to assess whether particular participant attributes affected their scoring of perceived natural character. While the overall data set was relatively large, some of the sub-groups used to analysis the potential impact of certain participant attributes were small. This limited the utility of some analyses. The predictor variables of gender, organisation, age category and self-reported level of familiarity with mangroves each affected the perceived scores for some (but different) photographs.

A very different study would be needed to determine participant perceived natural character scores for subtidal environments. Components would include a limited well-qualified group of participants and alternative tools such as carefully structured oral histories.

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9 Case studies using the QINCCE methodology

Abstract

The purpose of this chapter is to present the formal case studies, analyse lessons learnt and to suggest future work for fine tuning aspects of the QINCCE methodology. Because of ongoing methodology revision as part of the methodology development process, the case studies have been updated several times to address methodology changes. The natural character scores in the case studies are for 2009. For some units, the natural character indices and scores resulting from the use of 2009 data are inconsistent with what is depicted in the aerial images.

The Orongo Bay-Waikare Inlet and Omarino-Parekura Bay case studies used "standard-scale" digital aerial imagery (approximate date 2003). This imagery included the inshore coastal marine area as well as land. The Waipu and Ruakaka case studies used fine scale digital aerial imagery (approximate date 2005-2007). This imagery included the land and estuaries but largely omitted the open coast below mean high water springs.

The case study process led to a number of refinements to the QINCCE methodology, including: changes to the protocols or scoring systems used for measuring some of the parameters, amendments to the ecological naturalness index (ENI); and revision of the protocols for mapping and naming units.

9.1 Introduction

Methodology development is typically an iterative process. Each new idea or revision is tested with a "trial". After the trial the idea or revision is subject to further adjustments, rejected or confirmed. Sometimes a new idea replaces a formerly confirmed approach.

The iterative process used to develop the QINCCE methodology was described in chapter 2, while the QINCCE methodology itself is described in chapters 5, 6 and 7. Although the formal "case study phase" occurred at a time when methodology development was well advanced, this phase raised new questions and new perspectives which led to further refinement of the methodology.

Because of ongoing methodology revision as part of the methodology development process, the case studies have been updated several times to address the changes. It was not possible to completely restart the case study assessment from the start once the methodology had been confirmed. However, many of the parameters were reassessed for each mapped unit as practicable. This included all those parameters where there had been a change to what had been measured or changes to the parameter assessment/scoring system. The purpose of this chapter is to present the case studies, analyse lessons learnt and to suggest future work for fine tuning aspects of the QINCCE methodology.

9.2 Case study locations and characteristics

Appendix 2 summarises the main characteristics of the case studies, while Figure 2.2 shows their locations on Northland's east coast. The case studies address terrestrial coastal environment, intertidal and shallow subtidal environments with their final form being determined in part by the scope of the relevant aerial imagery. Additional provisional case studies were developed (Appendix 2) but insufficient resources were available for digitising their manually defined unit boundaries.

Two scales of aerial imagery were used. The Orongo Bay-Waikare Inlet and Omarino-Parekura Bay case studies used "standard-scale" aerial imagery obtained from Northland Regional Council. This imagery was only available in a digital format without standard contact prints. The date of the imagery was not available but is likely to be about 2003. The Waipu and Ruakaka case studies used fine scale aerial imagery which largely omitted the open coast coastal marine area. Estuaries were included. This aerial imagery was only available in digital format and as with the other case studies the date of the aerial imagery was unknown but is likely to be around 2005-2007. The spatial extent of these case studies was limited by the extent of this high resolution aerial imagery. The effective inland boundary in the Ruakaka and Waipu case studies represents the inland boundary of the available imagery, not the inland boundary of the coastal environment.

The case study locations incorporate: soft sediment exposed open coast (dunelands) and relatively sheltered estuaries in Bream Bay; and soft and hard sediment, sheltered and semi-sheltered waters of the inner and outer Bay of Islands. The Waipu and Ruakaka case studies were specifically selected because they are open soft-sediment (sand) coastal environments with dunes and estuarine river mouths with a range of development levels and types. There was also the bonus of fine scale aerial imagery.

The Omarino-Parekura case study was selected as an example of moderately sheltered coastline with rocky shore and estuarine environments. There are areas with relatively mature coastal forest and relatively intact estuarine sequences. Part of the area has been subject to recent major land use change including: logging (but not replanting) of plantations of the non-native radiata pine (*Pinus radiata*); and the conversion of farmland and some former plantation into an exclusive 19 lot coastal subdivision with large areas recently planted in native tree species. These recent land use changes are not shown on the aerial imagery.

The Orongo Bay-Waikino case study is from the inner Bay of Islands. There are rocky headlands and estuarine bays with mangrove forest and scrub. This case study also includes areas of recent land use change not shown on the aerial imagery. This land use change is focused around Orongo Bay where areas of former farmland and regenerating native and non-native scrub species have been converted into low density coastal subdivisions. Most of the sections have not been built on but the road network is in place along with some landscaping. With the oversupply of sections relative to buyers, and the poor financial state of some developers, some of the mainly native plantings have not been maintained. This case study also includes a number of marine farms in both Orongo Bay and the Waikare Inlet.

Given the Government commitment to fostering substantial growth of aquaculture (Ministry of Fisheries 2010) it was particularly appropriate that at least one case study included existing marine farms. To date Northland aquaculture has focused on oyster farming. Initially New Zealand rock oysters (*Saccostrea commercialis)* were farmed. In the 1970's spat of the non-native Pacific oyster (*Crassostrea gigas*) was introduced by accident. The oyster farmers found that the Pacific oyster grew faster and larger. Soon the introduced species replaced the native oyster in the farms. The Pacific oyster spread widely beyond the farms and now occurs in a wide range of intertidal environments. A number of the Waikare Inlet marine farms have only recently reopened after a four year closure due to norovirus contamination of exported Pacific oysters. The Omarino-Parekura Bay case study included one abandoned Pacific oyster farm on the eastern side of Parekura Bay. There were no marine farms in the Bream Bay case studies.

9.3 Case study methodology

The methodology used in the case studies initially followed that of earlier iterations of the QINCCE methodology. This was largely updated to reflect the final version as described in chapters 5, 6 and 7. Boundaries of relatively homogeneous units from the perspective of natural character were manually depicted on laminated paper prints of the aerial imagery. Each unit was given a unique identifier which included a case study location code (e.g. OR for Orongo Bay), a number based on its relative position along the coast, a code to depict the relative position in the landscape (S for sub-tidal, IT for intertidal, nc for near coast terrestrial and ic for inner coast terrestrial. The marked boundaries of each unit were digitised using ArcInfo software and each unit labelled. Tim Baigent of GeographX Digital Mapping digitised the manually depicted boundaries using funding from an Envirolink project.

The unit depiction was based on the land cover at the time of the field assessments (March-May 2009). As described in section 9.2, this has meant that some depicted unit boundaries may be inconsistent with the aerial imagery.

Data was collected for each core parameter on specially designed assessment sheets which were modified a number of times during the methodology development process. Some data was collected through aerial image interpretation (using paper prints, electronic files of aerial images and Google Earth). Given the significant changes in some areas since the date of the aerial imagery it was necessary to field check and refine the unit boundaries and those parameters initially assessed using aerial imagery. Other parameters were only assessed in the field-either by direct assessment or by viewing the unit from an alternative location (often the water). All the data was entered into spreadsheets which were periodically updated to address the revised methodology.

As described in chapters 2 and 8, a number of formulae options for the various indices and scores were tested. The linked database for each case study uses the revised formulae for calculating the: ecological naturalness index (ENI), hydrological and geomorphological naturalness index (HGNI), buildings and structures impact score (BSIS) and freedom from buildings and structures index (FBSI) and NCI (natural character index) and natural character score (NCS).

Parameter field data were also collected using earlier *Viewpoint* methodology for the Omarino, Parekura Bay, Waipu and Ruakaka case studies. This data was not able to be reassessed with the available resources and so is not included in this thesis. There were a number of trials of various *Tier Two* parameters. Again, the final suite of *Tier Two* parameters changed as part of methodology development. As this data could not be accurately reassessed it is not included.

The methodology for the marine and lake subtidal environments was developed after that for terrestrial coastal environments. It was not possible to obtain funding in time to complete the planned marine and coastal lake case studies.

9.4 Case study results and discussion

Aerial imagery showing the unit boundaries and the unit natural character scores are in Figures 9.1 (Ruakaka), 9.2 (Waipu), 9.3 (Orongo Bay-Waikare Inlet) and 9.4 (Omarino-Parekura Bay).

Figure 9-1: Ruakaka case study: natural character scores 2009

Figure 9-2: Waipu case study: natural character scores 2009

Figure 9-3: Orongo Bay- Waikare Inlet case study: natural character scores 2009

Figure 9-4: Omarino-Parekura Bay case study: natural character scores 2009

The natural character scores shown on the aerial imagery depict the situation in 2009. Given the previously discussed changes since the data of the aerial imagery some scores are inconsistent with the underlying aerial imagery.

Issues that arose during the case study data collection and analysis phases were used to help refine the methodology for measuring natural character of the coastal environment. Where possible the documented QINCCE methodology (chapters 5, 6 and 7) was used for the final iteration of the case studies. One aspect that could not be fully revised was the unit boundaries. These are not always fully consistent with the final boundary selection/unit definition criteria. The subtidal marine environment scores do not fully reflect the revised methodology for subtidal environments as this methodology was further revised after the completion of the case studies.

The case studies do not identify areas that address the 2010 New Zealand Coastal Policy Statement (Minister of Conservation 2010) “thresholds” of “outstanding” or “high” natural character as the policy statement was released more than one year after the completion of the case studies.

The natural character scores for the four case studies cover a large part of the possible 0 to 100 range although neither end is included in any case study. Those areas with the highest scores include:

- Locations where native forest regeneration is well advanced (e.g. parts of the eastern shore of Parekura Bay and the northern shore of Waipiro Bay and larger blocks of regenerating native forest such as that found behind Rawhiti in the eastern Bay of Islands, the southern shore of Waikare Inlet, and Waipu Cove)
- Young dunelands (including sand spits without vegetation) with no alien plants or where only a small proportion of plants are alien (e.g. the Waipu sand spit especially the area close to the river mouth, the sand spit on the south side of the Ruakaka River mouth).
- Remnants of kanuka forest on the dunes south of Ruakaka
- Remnant pohutukawa forest and trees in the Waipu Cove area
- Intertidal estuarine habitats in the southern arm of the Waipu Estuary

- Mangrove forest and scrub adjoining/along the lower reaches of tidal rivers and streams in all the case study areas
- Intertidal flats and intertidal rocky coast with little or no Pacific oyster (e.g. parts of Parekura Bay and the open Omarino coast)
- Saltmarsh (e.g. eastern shores of Parekura Bay)
- Freshwater wetlands adjoining saltmarsh and/or mangrove forest and scrub (e.g. Uruti Bay near Russell, Parekura Bay)

Lessons learnt during the execution and refinement of the case studies are discussed in the following sections.

9.4.1 Parameter measurement revisions

The case studies along with the perception study (Chapter 8) led to a number of refinements to the protocols used for scoring the core parameters. An example of a major change was the system used for scoring building and structure heights in the BSIS (Box 9.1). A minor change was to standardise the scoring system for building and structure colour naturalness and reflectivity. Refinements were also made to the scoring system for *Progress towards present-potential cover*, the mixture of parameters included in the ENI, and the scoring protocols for the hydrological and geomorphological parameters in the HGNI.

Box 9.1 Changes to the scoring system for measuring the impact of building and structure height

The *Freedom from buildings and structures index* (FBSI) is 1 minus the buildings and structures impact score (BSIS)

The initial approach to scoring the impact of building and structure height in the BSIS used a linear relationship between ‘median height’ and the associated ‘impact score’. This approach underestimated the impact of building and structure height on natural character as it would be virtually impossible to get a near-zero FBSI even for the downtown Auckland Central Business District. The two reasons for this are that the use of median height downplays the impact of a very tall building with a limited area footprint; and that even in central Auckland only part of a unit is occupied by buildings and structures taller than 30m (‘impact score’ of 1). In contrast a number of situations could lead to a near-zero ENI. It is also possible to have a near-zero HGNI (e.g. reclamation of seabed).

After experimenting with alternative scoring approaches it was decided that it would be preferable to use maximum rather than median height when scoring the impact of building and structure height. This is because the human eye is often drawn to the tallest item, especially where there is one tall building surrounded by lower buildings. A log growth curve (section 6.3.4) was selected over the previous linear relationship. This shows a more rapid rise in impact initially, tapering off as height continues to increase up to the maximum ‘impact score’ of 1 where maximum building and structure height is 30m and above. Heights above a maximum of 30 metres may have additional adverse aesthetic impacts which could be addressed separately outside of the natural character methodology.

9.4.2 Mapping protocol revisions

The case studies led to the refinement of the protocols for defining units of relatively homogeneous natural character. The undated digital aerial imagery was problematic at times. While a decision was made to map current ground cover irrespective of what was shown on the aerial imagery this made it difficult to accurately assess some parameters and define the boundaries for some units. It means that interpretation of the scores and unit boundaries for some locations can be confusing because the scores and unit boundaries are for a situation that differs from what is shown on the aerial image. Where the unit boundaries and scores do not appear to relate to the current aerial image, it is more difficult to check for errors and assess the timing and magnitude of change.

Where ever possible aerial imagery of a known date should be used. Where there have been many on-the - ground changes since the date of aerial imagery a decision needs to be made as to whether the boundaries of the units should be based on the situation at the time of the aerial imagery. Where a decision is made to depict units and measure parameters that differ from those depicted on the aerial imagery this should be clearly stated to reduce potential confusion by those interpreting the unit boundaries and the natural character scores. In some cases, new aerial imagery may be most appropriate.

Some may think that the availability of free satellite imagery (via Google Earth) replaces the need for aerial imagery. At this stage the imagery available via Goggle is of variable quality especially in more remote areas and areas of frequent cloud cover. In Northland much of the imagery was not of good quality and the aerial imagery provided by Northland Regional Council provided better resolution. Google imagery is not dated. Google imagery checked at the time of the case study assessments was at least several years old.

While GIS tools allow images to be viewed at a variety of scales, a working scale is still required. The working scale will depend on the purpose of mapping, the resolution of the aerial imagery, and the time and resources available. The scale used for unit depiction needs to be determined at the outset.

Where there is a small area that differs markedly from that which surrounds it (e.g. house and garden within an area of native forest and scrub) it can be tempting to map this small area as a separate unit. This was problematic in several of the case studies where these small areas could not be readily observed in the field. Such small units provide considerable scope for parameter assessment error. Very small units should be avoided if one is not absolutely sure what such a unit contains.

Having previous experience in vegetation mapping it was difficult to avoid the urge to frequently use vegetation boundaries as unit boundaries. Unit boundaries that follow vegetation boundaries are typically appropriate where the vegetation boundary reflects different levels of human disturbance (e.g. boundary between mature mixed broadleaved forest and young broadleaved scrub where the later has been subject to more recent disturbance). Using vegetation boundaries as unit boundaries can also be an appropriate where there are major changes in the relative proportions of native and introduced species; and/or changes in the parameters affecting hydrological and geomorphological naturalness. In the later situation the vegetation boundaries may be the obvious manifestation of other less visible changes.

Each unit needs its own unique identifier. The unique identifier is used to link the mapped boundaries to the unit attribute data. The original protocols used for naming units were intended to be logical, but as the trials proceeded some of the unit names became quite long and were not necessarily distinctive. An incremental approach to unit depiction also led to some units being “out of sequence” which could be confusing. In addition the use of ‘near coast’ (nc) and ‘inner coast’ (ic) were not necessarily applied consistently because of iterative process of unit boundary definition. For future use it is suggested that a simpler identifier system be used (e.g. the location code, a number with a letter, e.g. ON1a, ON1b, ON1c. An extra letter can be used where it is necessary to subdivide a unit as part of a more detailed assessment e.g. ON1af. It may still be appropriate to distinguish aquatic units from terrestrial units.

9.4.3 The ecological naturalness index

The penultimate version of the methodology for measuring natural character and its change included a parameter *percent of the canopy that is composed of native species.* As a directly measured parameter, it was favoured because it seemed to be robust. However, repeated testing of the formulae for calculating the ENI and the NCI showed that the inclusion of this parameter within the ENI led to double counting of the impact of introduced species on ecological naturalness (Chapter 8). The double counting came about in those areas that received a lowered score for *progress towards present-potential cover*–largely or partly because they were dominated by introduced species. As a consequence the ENI and the NCI for units dominated by pasture and/or pine plantations were very low.

To address this problem the parameter *percent of the canopy that is composed of native species* was deleted from the core parameter set. The scoring system for the parameter *progress to present-potential cover* was subsequently refined to directly and consistently address the proportions of native and introduced species in the top tier/canopy/benthic cover.

The penultimate version of the ENI addressed only stationery or relatively stationery biota. As this was an ecological index it was decided that some assessment of the naturalness of the mobile biota was required. It was not practical to undertake quantitative assessments of the distribution and abundance of selected mobile species for a core parameter. Instead it was decided to use a categorical assessment of the key pressure on mobile biota. For terrestrial coastal environments the major nationwide threat to indigenous birds is the abundance of introduced mammalian predators. In the marine environment the primary pressure is the human harvesting of mobile biota. For coastal freshwater environments the major pressure is introduced fish species. The scoring protocols for these parameters are discussed in section 6.2.2.

9.4.4 Definitions of categories for percent cover and other estimates

Earlier forms of the methodology carefully distinguished between natural area, biological artefact area and natural surface because they were treated slightly differently in the ENI formula. The final ENI formula (section 5.5) treats these categories in the same way. This means that the distinctions between these forms of cover are not critical for the proper operation of the methodology. They can still be a useful way of organising data. In those cases where such distinctions are not helpful they do not need to be used. For example, an area of rough grassland that does not seem to be being farmed can be treated as either biological artefact or natural area for the purposes of the ENI formula. In some detailed assessments it may be useful for the purposes of scoring *progress towards present-potential* *cover* to be able to distinguish between several types of biological artefact area or several types of natural area.

Although district plans may carefully distinguish between buildings and structures for the purpose of the plan rules, a precise distinction is unnecessary for the purposes of the methodology for measuring natural character. The same parameters are assessed for buildings and structures and they are treated in the same way in the BSIS and FBSI formulae.

9.4.5 Hydrological and geomorphological naturalness parameters

The case studies demonstrated that there was a need to develop separate scoring protocols for off-site versus on-site hydrological and geomorphological impacts. They also demonstrated that more detailed scoring protocols were required for the hydrological and geomorphological naturalness parameters.

For the on-site impacts on hydrological and geomorphological naturalness parameters Table 6.3 (scoring protocols) was expanded to include new activities and to provide more guidance for scoring different levels of some activities (e.g. different levels of cut and fill earthworks). One aspect that would benefit from further consideration is the scoring system for the impacts on hydrological and geomorphological naturalness of sealed surfaces, including paving and roofs. These sealed surfaces reduce in-situ permeability (on-site impact) thereby affecting downstream flow regimes (off-site impact). While this was not a major issue for the majority of case study units it is highly significant in some coastal locations. More work is required to develop appropriate scoring protocols.

Protocols have been developed for off-site impacts on hydrological and geomorphological naturalness parameters (Table 6.4). These protocols address:

- Altered sediment regimes and altered currents caused by a causeway or similar structure
- Accelerated (often estuarine) sedimentation associated with a river that has a modified catchment

- Accelerated sedimentation from groynes along marine shorelines
- Displaced erosion (off-shore or down current erosion caused by a seawall)

It is difficult to determine sedimentation rate baselines and changes without some knowledge of the historical changes that have occurred within the catchment or marine sediment transport system. More work is needed to determine scoring protocols for the off-site impacts of contaminants resulting from leachates (e.g. from poorly sealed landfills) and discharges. This was not a significant issue for any of the case studies.

9.4.6 Perception and thresholds for natural character

Some of the natural character assessments in the case studies may surprise some people. In part this is because some interpret natural character as primarily being an absence of buildings and structures (Fairweather & Swaffield 1999). People are not necessarily aware of the variety of components that make up natural character and many lack knowledge about what is natural in a particular environmental context. For example, people do not necessarily know which organisms are native.

People's values and perceptions also colour how some natural phenomena are viewed. In northern New Zealand the spread of mangroves in some locations is viewed by some people as a matter of concern. Evidence to date indicates that mangroves have generally responded to hydrological and sedimentation regimes that have been changed by human actions to be more favourable for mangrove establishment. In other places mangroves have recolonised areas they formerly occupied but had previously been removed by earlier human actions (Appendix 5).

There can be major differences in perception as to what is natural, particularly with some types of coastal environment (e.g. subtidal rocky reefs, former dune and wetland complexes). In heavily developed or exploited areas this can lead people to accept as "natural" higher levels of anthropogenic modification. This may be appropriate in the context of protecting what is left, but not so helpful for restoration. In this context the lower expectations of naturalness may be result of the shifting baselines syndrome as described by Pauly (1995) for fisheries scientists (Box 9.2). The 'shifting baseline' syndrome can be observed in many other environments and contexts.

Box 9.2: Shifting baseline syndrome

As described by Pauly, shifting baselines occur because each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the start of their careers. This 'baseline' is then used to evaluate changes. Over time this leads to a gradual downward shift of the baseline, an acceptance of losses and the use of inappropriate reference points including rehabilitation targets. Examples of shifting baseline syndrome include dramatic declines in fish and other exploitable organism biomass along the North Atlantic coast of Canada to 10% of that two centuries ago (Pauly 1995), changes in the mean size and abundance of New Zealand snapper over the last 40 years unrecognised by fishers (Parsons et al. 2009), and the lack of recognition of the impacts of artisanal/'small-scale' fishers in many areas including the Caribbean, Indian Ocean, South Pacific and Australia (Pinnegar & Engelhard 2008a).

The methodology uses standardised reference conditions (e.g. Chapter 7) where the low/no-human-impact state is the most natural. As there is no qualifier on natural character in the legislation (Chapter 4) changes to any level of natural character is relevant. The QINCCE methodology is well suited for measuring changes to natural character, irrespective of the initial state of natural character. As the calculated indices and scores are based on standard reference conditions the scores are not context dependent. This allows for aggregation and comparison where there are different environment types and/or between different locations.

The 2010 New Zealand Coastal Policy Statement (NZCPS) (Minister of Conservation 2010) sets two policy-thresholds for coastal natural character (Policy 13(1)). Areas with at least "high" natural character are to be mapped (or otherwise identified) and the adverse effects of activities are to be avoided for areas of "outstanding" natural character. As these policy-thresholds are comparative terms then context is important. There are two main types of context that are relevant: environment type and location.

Some coastal environment types have been subject to greater natural character losses than others. For example coastal floodplains in most of New Zealand have very little natural character remaining and even very small remnants of indigenous forest in these environments are likely to considered “outstanding” or at least highly natural in the context of that environment type. By comparison much of the natural character of offshore marine environments remains (apart from the physical and ecological impacts of harvesting marine biota). Given the nationwide disparities in natural character loss amongst different coastal environment types, it would be appropriate for the QINCCE numerical triggers for the NZCPS policy-thresholds to be set at levels that reflect the prior variation in losses of natural character for different environment types.

Some regions in New Zealand have been subject to greater losses of terrestrial and near-shore coastal natural character than others. In highly developed regions few, if any, sites will fit into the low human impact category and so few areas show natural character that is “high” relative to the no-impact reference condition. This is a concern to those in heavily developed regions such as Auckland (Boffa Miskell Limited 2002). While it would be appropriate for a single national assessment of natural character to use the same natural character scores to trigger the NZCPS policy thresholds of “high” and “outstanding”, this is not necessarily the case for regional or district assessments .

For a regional assessment it would be appropriate for the policy-thresholds to be determined in the context of that region. This means that where a region has experienced greater natural character loss, it would be appropriate to set the QINCCE numerical triggers for the regionally “high” and “outstanding” policy-thresholds at a lower level than would be set for regions with sections of near pristine coastlines such as Fiordland. This could be used to ensure that each region was assessed to contain at least some comparatively “outstanding” coastal natural character where adverse effects on natural character are to be avoided (NZCPS policy 13(1)(a)).

9.5 Future work

Further testing via case studies is recommended for those coastal environments where the methodology has not been so extensively tested. The first priority would be the different types of marine subtidal environment. More work is also recommended for estuarine intertidal flats, dunelands and coastal lakes. It would be particularly helpful to develop better tables for scoring progress towards *present-potential cover* in these environments. It would also be helpful to trial the application of the QINCCE methodology at a regional scale to determine the appropriate level of unit depiction in different circumstances.

The level of sensitivity of the QINCCE methodology for detecting change was not determined for the case studies as insufficient resources were available to retrospectively apply the revised methodology to an earlier set of aerial images. It is suggested that future research could determine the sensitivity of the methodology for several scales of application and several levels of precision in different types of coastal environment. Sensitivity applies to particular combinations of circumstances (scale the method is being applied at, precision of method application) because it is not an absolute property of the methodology.

As part of the sensitivity testing it is suggested that two alternative approaches to the assessment of change be compared. In the first approach the unit boundaries would remain unchanged between time periods. The second and preferred approach is that unit boundaries would be altered for areas where environmental change shows this would result in more homogeneous units from the perspective of natural character. In this case change could be assessed using a “grid” overlaying the mapped units. Each point on the grid would be assigned the score for the unit it lies within for each time period. It is suggested that alternative ways of reporting change be assessed, including absolute and relative (or percentage) change. The latter is likely to be most useful for areas where natural character has already has been substantially modified but some natural character still remains.

Another possible case study topic would be to explore options for combining data from the Tier 2 parameters for different types of coastal environment. These case studies could also be used to trial approaches for combining data collected from the *viewpoint* and plan view perspectives.

A further potential case study topic would be to determine appropriate QINCCE natural character score triggers for the NZCPS policy-thresholds of “high” and “outstanding”. This could consider appropriate triggers for different coastal environment types and for different regional contexts.

9.6 References

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10 Conclusion

10.1 Addressing the research objectives

The overall objective of this research was: *To develop a robust quantitative methodology to measure natural character and its change, and thereby measure performance in implementing the New Zealand natural character statutory policy goals.* A robust quantitative methodology (QINCCE (Quantitative Index for measuring the Natural Character of the Coastal Environment)) has been developed. This methodology can be used for terrestrial and aquatic coastal environments. For each broad class of coastal environment, a core set of parameters is used to calculate three sub-indices (ecological naturalness index (ENI); hydrological and geomorphological naturalness index (HGNI); and freedom from buildings and structures index (FBSI)) for each plan-view unit. These sub-indices are combined to give an overall natural character index for each unit. Many levels of natural character distinction are possible. The QINCCE methodology can be applied at a range of scales, including at the district or regional scale. This and other features mean that the QINCCE methodology can be used to measure natural character change and therefore the effectiveness of mechanisms used by agencies to implement the natural character statutory policy goals.

Each of the nine research questions posed in the Introduction (Chapter 1) has been addressed. A comprehensive definition of natural character for the New Zealand environmental, legal and policy context has been developed and the role of perception in this definition clarified (Chapter 3) as follows:

Natural character occurs along a continuum. The natural character of a "site" at any scale is the degree to which it:

- *is part of nature, particularly indigenous nature*
- *is free from the effects of human constructions and non-indigenous "biological artefacts"*
- *exhibits fidelity to the geomorphology, hydrology and biological composition, structure and pattern of the reference conditions chosen*
- *exhibits ecological and physical processes comparable to reference conditions*

Human perceptions and experiences of a 'site's' natural character are a product of the site's biophysical attributes, each individual's sensory acuity, and a wide variety of personal and cultural filters.

This definition of natural character (Objectives 1, 2 and 3) is consistent with the overall tenor of interpretations of natural character in 100 decisions made by the New Zealand Environment Court/former Planning Tribunal and higher courts (Chapter 4). It provides an appropriate framework for indicator selection for the QINCCE methodology.

The QINCCE methodology (Chapter 5) uses indicators (and environment-specific parameters) based on the definition of natural character (in Chapter 3). It uses a consistent framework for measuring natural character across terrestrial, freshwater and marine coastal environments and can be applied at a range of scales and for a range of purposes (Objective 4). The core parameters measure key components of environmental naturalness at a level that is practical for widespread application (Chapter 5). Where additional detail is required, *Tier-Two* parameters and alternative assessment perspectives (beyond the standard plan-view perspective) are available (Chapter 6) (Objective 5). The analysis framework aggregates core parameter data using indices that can be combined into an overall natural character index. The standardised construction of the indices (all scoring between 0 and 1) allows the results from different types of coastal environment to be compared (Objective 6).

The QINCCE methodology uses reference conditions (e.g. *present-potential cover* and *present-potential natural state*) to facilitate the aggregation and comparison of results from different types of coastal environment (Objective 7). Scoring tables have been developed to: measure progress towards *present-potential cover*; and to determine how closely current hydrological and geomorphological condition matches *present-potential natural state.* Trials in Northland demonstrated the application and utility of these reference conditions and the associated scoring tables.

As part of the methodology development process, 113 "informed" participants scored their perception of the level of natural character in 40 coastal environment photographs. These scores were compared with scores calculated for the same photographs using the QINCCE *Viewpoint* perspective (Chapter 8). The results assisted the refinement of: the final selection of parameters in the Ecological Naturalness Index (ENI); scoring protocols used for several parameters; and the formula for combining the sub-indices into an overall natural character index (Objective 8). Certain attributes of the participants (e.g. age category, organisation category) were related to different scoring for some of the photographs (Objective 9). Further assessment using more tightly prescribed photograph sets may provide further guidance on how particular attributes may affect perception and scoring in particular situations.

10.2 Contribution to knowledge

Key contributions to knowledge in the field of environmental policy analysis include the development of a comprehensive definition of natural character that incorporates reference conditions; the systematic analysis of 100 New Zealand Court decisions about natural character; and the comparison between the case law analysis and the definition of natural character. The case law analysis systematically identified key patterns in Court interpretations of natural character and expected natural character outcomes.

The development of robust quantitative methodology for measuring the comprehensive definition of natural character across the different types of terrestrial and aquatic coastal environments, and at a range of scales, is an important contribution to scientific knowledge. Specific contributions to knowledge include the indicator and parameter sets; assessment and scoring protocols for measuring specific parameters; protocols for the use of different perspectives for natural character measurement; methodology for constructing reference conditions and the development of scoring tables for measuring progress toward (or fidelity with) these reference conditions; and the construction of the natural character sub-indices and overall natural character index.

The use of reference conditions- *present-potential cover* and *present-potential natural state*- in assessments of land/seabed cover naturalness and hydrological and geomorphological naturalness, respectively, provide a mechanism for comparing the naturalness of very different types of coastal environment.

At a broader level, this thesis demonstrates the development of a series of quantitative indices based on combining the results of measured and derived parameters for very different environmental characteristics. It has shown how perception data from “informed” participants can be used to refine measurement and analysis protocols for the complex concept of natural character. The concepts of *present-potential cover* and *present-potential natural state* and the methodology developed for evaluating progress towards *present-potential cover* can be extended to other situations where a scalable rapid assessment of ecological naturalness is required.

10.3 Application of the methodology and future research

Extensive testing and revision has resulted in a robust methodology that can be used to measure performance in implementing New Zealand’s natural character statutory policy goals. The methodology can be used for

- Implementing that part of policy 13 in the 2010 New Zealand Coastal Policy Statement (NZCPS) that requires councils to assess the natural character of the coastal environment and take various actions depending on the level of natural character present
- Measuring natural character and monitoring its change over time at a range of scales ranging from a single site to a district or region
- Measuring natural character and monitoring its change for and across different types of environmental systems
- Monitoring change in the components of natural character via a suite of indices and the underlying parameters
- Providing a framework for predicting and evaluating the impacts of different development or management scenarios on coastal natural character
- Contributing to council spatial planning frameworks
- Developing and monitoring coastal environment restoration programmes

- Evaluating possible natural character outcomes where different actions have different timings (e.g. immediate construction impacts versus the delayed expression of planting trees to mitigate those impacts)
- Providing a quantitative framework for natural character mitigation design and assessment

The QINCCE methodology has been most extensively tested and refined for terrestrial and intertidal environments. Further testing via case studies is recommended for those coastal environments where the methodology has not been so extensively tested. The priority would be different types of marine subtidal environments.   It would be particularly helpful to develop better protocols for scoring progress towards *present-potential cover* in these environments.

The level of sensitivity of the QINCCE methodology for detecting and measuring natural character change depends on the scale of methodology application and the precision with which the methodology is applied. This means that the level of sensitivity is determined for a particular application or project. The level of sensitivity was not determined for the case studies (in Chapter 9) as insufficient resources were available to retrospectively apply the revised methodology to an earlier set of aerial photographic images. It is suggested that future research determine QINCCE methodology sensitivity levels for several scales of application and several levels of precision for different classes of coastal environment.

As part of the sensitivity testing, it is suggested that two alternative approaches to the assessment of change be compared. In the first approach the unit boundaries would remain unchanged between time periods. The second and preferred approach is that unit boundaries would be altered for areas where environmental change shows this would result in units with higher levels of natural character homogeneity. In this case change could be assessed using a fine-scale grid overlaying the mapped units. Each point would be assigned the score for the unit it lies within for each time period.

For detailed site-based assessments of natural character it would be useful if there was further development of some *Tier-two* parameters, especially to determine the appropriate units for measuring change. Other future work could include testing options for: combining and reporting data from *Tier-two* parameters; and combining the *Viewpoint* and plan view perspectives for data analysis and reporting purposes.

Arising out of the 2010 NZCPS and the case studies (Chapter 9) a suggested area of further methodology development would be to apply the QINCCE methodology at a less –detailed scale than has been used to date – specifically that which would be used to assess coastal natural character for an entire region. This work should identify the intensity of unit depiction that would be appropriate for different circumstances. It would also be useful to trial potential criteria for setting natural character protection and restoration thresholds in different circumstances.

10.4 Application of the research beyond New Zealand

This thesis defines natural character for the New Zealand context and describes quantitative methodology (including a set of indices) developed to measure the natural character of the New Zealand coastal environment. Although this thesis has focused on New Zealand and the measurement of progress towards its statutory natural character policy goal, the methodology framework for measuring natural character/environmental naturalness can be adapted for use in environments outside of the New Zealand coastal environment.

For example, in the definition of natural character (Chapter 3), ecological, hydrological and geomorphological naturalness are assessed against "reference conditions". In the New Zealand context *present-potential* reference conditions are used for some parameters. . New Zealand was the last major land mass to be settled by humans, with this settlement occurring about 700 years ago. As such it is recognised that it is more practical to determine "*present-potential*" state for New Zealand than for areas where there is a long history of human settlement and human-mediated environment perturbation and change. For those areas with a long history of human settlement and activity (e.g. Europe, Africa) alternative reference conditions are likely to be more suitable. A similar reference condition to that proposed for New Zealand use may be suitable for other relatively recently settled areas such as Madagascar and various smaller island groups. Research would be required to determine appropriate reference conditions for different contexts.

The methodological framework developed for the quantitative measurement of natural character/environmental naturalness (using the comprehensive definition in Chapter 3) could be adapted to other environments and jurisdictions. The indicators should apply generally. Parameters specific to different New Zealand coastal environments could be replaced by parameters more relevant to the particular environment/jurisdiction being addressed. Such replacement parameters should have equivalent intent and action as the parameters they are replacing. This will then retain the integrity of the formulae used for the natural character indices. Testing would be required to verify this.

10.5 Preserving and measuring natural character/environmental naturalness beyond the New Zealand coastal environment

In New Zealand preservation of the natural character of coastal and various freshwater environments is a national policy goal that has been incorporated into resource management and protected area legislation. Some other national jurisdictions have policy goals to preserve environmental naturalness for specific areas (e.g. USA wilderness legislation). The assessment of environmental naturalness can be an important part of biodiversity condition assessment procedures and management of areas for biodiversity protection purposes.

As global human populations continue to increase and human impacts on the natural world accelerate in many locations, global environmental naturalness levels are likely to decline. Natural character /environmental naturalness will become an increasingly scarce resource. In this context it will become increasingly important that there be a robust quantitative methodology for measuring natural character/environmental naturalness across a broad range of environments. The methodology framework developed in this thesis could potentially be adapted for this purpose. Without such a methodology and its ongoing application, the loss of global natural character/environmental naturalness will not be measured consistently, and is less likely to be managed appropriately.

The wider international adoption of national, regional and local policy goals to preserve, protect or restore natural character/environmental naturalness would be valuable, especially for coastal environments. Many coastal environments are especially vulnerable and subject to intense development and resource exploitation pressures. Policy goals for natural character/environmental naturalness could provide an alternative lens or perspective for the administration and management of global coastal environments. Such policy goals require methodology such as QINCCE to measure performance and ensure that policy goals are being met.

Appendices

Appendix 1: Early methodology trials: site summaries

Location	**Type of coastal environment assessed in the first round of methodology trials**	**Major issues for natural character measurement methodology**
Mangawhai Estuary	Estuary mouth, developed estuary margins, open coast to the north including developed public access area	The naturalness of an estuary mouth where the current position has required much human effort to maintain; Potential impacts of sand mining south of the sand spit; Highly developed public access areas that are designed to minimise overall ecological impact
Waipu Cove, Waipu River Estuary	Entire estuary, entire Waipu dune system including highly modified and undeveloped areas, coastal escarpment, coastal catchments including residential settlement, native forest, plantation pine forest, agriculture	The effects of a training wall on natural character The natural character effects of periodic sewage leaks to a small estuary; The naturalness of particular dune blowouts Determining the natural vegetation endpoint for more stable areas of dune The naturalness of wildlife, especially for ecologically important estuaries
Uretiti Beach	Dunelands	The effects of vehicles on dune naturalness The naturalness of dunes where there is narrow area of native sand-binders on the foredune face but extensive alien plant invasion inland of that
Ruakaka Coast & Ruakaka Estuary	Dune system including sand mining, whale burial site, high public use and areas set aside for bird breeding and roosting, estuary mouth, residential development	The effects of sand mining of stored sand on naturalness including the creation of ponds that potentially benefit wildlife; The effects of whale burials on dune naturalness ; Dune planting & stabilisation with non-native species (e.g. marram, gazania); the effects of vehicle use on the beach; “fenced” areas to prevent humans entering dotterel breeding areas The natural vegetation of consolidated dunes
Marsden Point	Dunelands and harbour entrance,	The effects of very large buildings and structures (e.g. Marsden B

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measurement methodology
to One Tree Point	residential development, race course, Marsden B power station, Marsden Point including the oil refinery and port operations, wharves, Marsden Cove Marina (still being constructed)	power station) on the dune naturalness ; The extent to which planting mitigates the effects of large buildings & structures Determining the context of natural character impacts of the Marsden Point Oil Refinery and wharves given its location on duneland opposite volcanic rock headlands with native vegetation Addressing natural character impacts of Marsden Cove Marina which is largely being created by excavation from land
Bream Head to Onerahi: Whangarei Harbour	Open bays with rocky headlands, native forest and scrub, small settlements, mangroves, marine reserve	Assessing the natural character impacts of a water margin roads Comparing naturalness of marine reserves with similar habitats not in marine reserve
Whangamumu Harbour and nearby open coast	Small harbour, extensive pohutukawa dieback around harbour margins	Addressing the natural character impacts of extensive dieback of the iconic pohutukawa along parts of rocky coast Northland
Waikare Inlet, Inner Bay of Islands	Large inlet with estuarine habitats in the many arms. Some of these estuarine areas include extensive areas of tall mangroves. Catchment is mainly low intensity agriculture and native forest and scrub. Extensive areas of Pacific oyster marine farms. addressing the effects (including sedimentation and debris) of derelict Pacific oyster farms on	The extensive colonisation of intertidal by Pacific oyster Addressing estuarine natural character when water quality decline is from offsite causes that are not upstream e.g. Lower Waikare Inlet's relatively poor water quality and increased sediment and nutrients are derived from the Kawakawa River Assessing the naturalness of intensive mooring areas

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measurement methodology
	natural character	
Opua, Veronica Channel, Te Waihapu, Matauwhi Bay: Bay of Islands	Terrestrial rocky coast, bays with mangroves at head, marina and reclamation, houses amongst vegetation	Identifying intertidal and subtidal alien species impact in waters with low water clarity (e.g. 13 alien marine species have been recorded from the Opua area but water visibility is almost always low) Assessing the naturalness of intensive mooring areas Addressing the naturalness of structures that are both over water and in the water column Exhibiting "character" (e.g. old style buildings on poles over the water) versus natural character Assessing the effects of dredging on natural character
Paihia-Waitangi	Sand and rock shore with wharves and commercial buildings over water, commercial development on waterfront	Assessing the natural character effects of sea walls, and intensive water margin development (including a planned water front commercial expansion with dredging and more walls)
Whangae River (tidal reaches) & catchment	Tidal reaches with primarily mangrove margins, terrestrial margins	Addressing the natural character effects of an old (150 year?) railway causeway and bridge across the bay entrance and identifying the ecological resets Addressing the natural character impacts of coastal landfills and re-contouring
Waikino River (tidal reaches) & catchment	Relatively unmodified estuarine habitat including tall mangroves, extensive area of saltmarsh, catchment largely in native scrub and forest	Mapping and labelling units that cross into other catchments
Haumi River (tidal reaches) & catchment	Estuarine habitat including mangroves and saltmarsh, catchment residential development, upper catchment agriculture	Addressing natural character impacts of road causeways across bay entrances Addressing natural character effects of cutting down mangroves

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measurement methodology
Russell- Tapeka Point, Bay of Islands	Rocky shore, small sand beaches, rocky peninsula with patches native regeneration and some remnant pohutukawa	Mapping and labelling units on very narrow peninsulas with different types of shoreline Measuring colour and reflectivity of residential buildings in a unit where there is considerable variation in building colour and reflectivity Defining unit boundaries where there are different types of areas at a scale too small to map (e.g. collection of small but diverse types of public space) Addressing new developments that are not shown on the aerial images, especially where it is not possible to get close enough to accurately pinpoint the precise location Addressing the effects of pest plants on natural character
Outer eastern Bay of Islands group and subtidal	Predominantly rocky shore with some cliffs/ escarpments, much of terrestrial area in native regeneration, some houses on private land, grazing and open grass areas on Urupukapuka, subtidal sea grass, subtidal sand flats and rocky coast	Addressing the upcoming total vertebrate pest eradication programme Evaluating the effects of anchoring damage on subtidal sea grass beds Evaluating the effects of extensive marine animal harvesting on the naturalness of subtidal and intertidal ecological communities Addressing the effects of commercial and recreational boat traffic, especially noise
Purerua Peninsula	Outer coast with pasture, few buildings and some small remnants of native vegetation	Determining the extent to which extensive ecological restoration work (e.g. intensive pest control, planting of native plants) offsets the impacts of structures, and how this may vary in different contexts
Cavalli Islands	Rocky islands mostly with native regeneration. Subtidal sand and rocky reefs	Assessing the impacts of extensive networks of nets/pots and buoys (presumably temporary) Addressing water clarity variation due to current locations, speed and direction Identifying what constitutes a “natural” subtidal north-eastern rocky coast

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measurement methodology
Mahinapua Peninsula and coast to the south east, Flat Island and subtidal	Narrow peninsula, small coastal settlement, subtidal sand and reefs	Addressing the natural character impacts of locally damaging activities within a settlement Identifying vegetation endpoints for locally different geology and soils
Whangaroa Harbour & adjoining sections of open coast	Outer Harbour terrestrial environment includes hill slopes (often steep) with primarily native vegetation; inner harbour with pasture, pine plantations, native vegetation and several small settlements; variety of aquatic environments including a marina & estuarine flats in the inner harbour. Outer coast is rocky with subtidal reefs and largely native vegetation on steep hills. Two settlements in sandy bays to east and west of Harbour	Addressing the effects of derelict and operational Pacific oyster farms on natural character Distinguishing between naturalness and the spectacular (Pekapeka Bay area)
Stephenson Island and subtidal	Grassed island with little native vegetation, subtidal reefs	Addressing the natural character impacts of scattered Pacific oysters in a locality away from past or present oyster farms Distinguishing between “naturalness” and remote/”wild”
Mangonui Harbour	Outer harbour including the settlements of Mangonui and Hihi	Assessing natural character in locations where much of an environment is used for moorings Distinguishing between having character (e.g. buildings over the water)

Location	Type of coastal environment assessed in the first round of methodology trials	Major issues for natural character measurement methodology
		and natural character
Berghan Point and mainland coast to east and west, including subtidal	Open coast rocky shore. Land uses primarily extensive pastoral faming and regeneration of primarily native species	Assessing the natural character impacts of blocks of pine trees in a grass landscape Addressing the extensive dieback of coastal cliff of the iconic pohutukawa
Karikari Peninsula, including subtidal	Northern peninsula including extensive scrub area, motor camp, extensive forestry areas (some being cleared); subtidal rocky coast north eastern shore and NW islands	Addressing the natural character impacts of large scale conversion from pine plantation to residential sections Identifying what constitutes a “natural” subtidal north-eastern rocky coast

Appendix 2: Case study site summaries

Location	**Type of coastal environment**	**Case study commentary**
Omarino--Parekura Bay, Outer Bay of Islands	Rocky coast, estuarine arms, several small settlements, forestry, low intensity agriculture, native forest & scrub including relatively mature areas of mixed broadleaved forest	There has been a lot of change in the NW sector of this area (Omarino-Benson Farm) since the date of the aerial images. Former pine plantation and pasture has been planted in native species, roads of a high standard have been built and the entire area has subdivided into large exclusive lots. To date building activity has focused on facilities in Waipiro Bay and on one north-facing lot. Much of the forestry in the west (Waipiro Bay) has been recently logged. The existing settlement areas in Waipiro Bay and Te Uenga Bay contain a wide range of residential building styles and contexts. The mature mixed broadleaved forest in the SE along the coastal margins (Parekura Bay) is some of the most mature water's edge native forest in the Bay of Islands. This area contains some low density housing. There is one abandoned Pacific oyster farm on the eastern shores of Parekura Bay. Pacific oysters are spreading through the entire Parekura Bay intertidal habitats
Orongo Bay-Waikare Inlet, Inner Bay of Islands	Estuarine habitats. Extensive areas of marine farms The terrestrial coastal environment is mixed native vegetation and low intensity agriculture.	There has been a lot of change in landward Orongo Bay since the date of the aerial images. Relatively extensive areas of previously abandoned farmland have been converted to low intensity "coastal living" subdivisions or are in the process of being converted. Few houses have been built. To the north of the conversions to subdivision are the Russell landfill and wastewater treatment plant on the southern outskirts of Russell (not included in the case study). Pest plants are common near Russell. Orongo Bay is one of the densest areas of marine farming structures in Northland and New Zealand (Rennie 2002). On the other side of the Peninsula is the middle section of Waikare Inlet. There is a relatively large area of marine farms in this part of the Waikare Inlet, especially Ngangeroa Creek area. Most, but not all, Pacific oyster marine farms in the study area have remained

Location	Type of coastal environment	Case study commentary
		operational during the harvesting ban. The southern shore of Waikare Inlet contains relatively extensive areas of regenerating native scrub and forest. The coastal marine area contains marine farms, one of which has remained operational during the harvest ban. The case study includes a small section of the relatively unmodified Waikino Creek area.
Waipu Cove and Waipu River Estuary, Uretiti Beach; Bream Bay	Open coast dunelands, small estuary, intensive agriculture, forestry, residential settlement and native scrub and forest in adjoining terrestrial coastal environment	This cases study uses higher resolution images which unfortunately exclude both the open coast below about mean high water and some of the inner coastal environment. This case study covers a diverse range of natural areas as well as a diversity of human impacts. There are areas of natural vegetation, including some relatively unmodified dune land. The small estuary is important for its wildlife values, especially as a breeding area. There are cliffs with tall remnant pohutukawa trees. There are areas of relatively mature coastal indigenous forest. Land uses include residential settlement, lifestyle lots, variety agricultural activities and forestry
Ruakaka Beach settlement and Ruakaka River Estuary	Open coast dunelands with a variety of vegetation types, estuary and escarpment. This includes residential settlement as well as unsettled areas	This cases study uses higher resolution images which unfortunately exclude the open coast below about mean high water. It includes a diverse range of uses and states for duneland and estuarine environments. The uses include residential development of different ages, beach access facilities, large motorcamp, planted forest and logged forest. There are areas of natural vegetation (dune and estuarine) and the estuary area is important for its wildlife values
Motorua and Motukiekie Islands, Eastern Bay of	Rocky shores with a few sandy bays. Predominantly native	These islands are largely regenerating naturally with active removal of plant pests in many areas. Motorua Island is largely Crown owned (Department of Conservation) with some private holdings in the south-east. The private land

Location	Type of coastal environment	Case study commentary
Islands outer islands and surrounding subtidal*	vegetation with some weed species. Some private development. Subtidal sand and rocky reefs	contains houses near the water margin. In the eastern part of Hahangarua Bay there are several newer buildings designed to blend into the environment and landscaped with native plants, while the older buildings in the east of the Bay are surrounded by many introduced plants. Motukiekie Island is privately owned. The house and associated facilities are in the northwest. The owners are removing some of the introduced trees. These two islands are part of the area where there is a programme to eradicate all vertebrate pests There is intensive recreational fishing and boating in some areas at times.
Opua marina and settlement, Inner Bay of Islands*	Estuarine environment, marina, reclamation with marine servicing environments, buildings over water, causeway	This case study includes a moderate sized marina, reclamation with marine servicing activities, buildings over water, causeways associated with the old rail line, extensive boat mooring areas and residential settlement often within largely native vegetation on hillsides. Pest plants are common on the hills, especially near the marine servicing areas

*Units were depicted and parameters measured but resources were insufficient for the digitizing of mapped units

Appendix 3: Summary of Resource Management Act court decisions where natural character is an important element in decision-making

Appendix 3: Summary of court decisions where natural character is an important element in decision-making																							
Decision number	Decision name	Rural /Lifestyle subdivision	Residential subdivision	Buildings & structures	Quarry/mining	Other terrestrial	Marine farms	Marinas /ports	Jetties/wharves	Other aquatic	Plan provisions excluding designations	Requirement	Coastal environment	Terrestrial	Aquatic	Water surface	Discretionary activity	Non complying activity	RCA	High Court or Court of Appeal	EC Auckland	EC Wellington	EC Christchurch
A154/2005	Adventure Specialities Trust v Whangarei District Council	1											1	1				1			1		
W71/97	Aqua King Ltd (Anakoha Bay) v Marlborough District Council						1						1		1	1	1					1	
C126/97	Aquamarine Ltd v Southland Regional Council									1					1	1		1					1
A115/99	Arrigato Investments and Evensong Enterprises Ltd v Rodney District Council, Aukland Regional Council	1											1	1				1			1		
CA84/01	Arrigato Investments and Evensong Enterprises Ltd v Rodney District Council, Aukland Regional Council																			1			
A119/99	Ashton, T.F. v Rodney District Council								1				1		1	1					1		
A203/2002	Auckland Volcanic Cones Society Incorporated & Greenbelt Incorporated & others v Transit New Zealand											1		1							1		
A3/94	Bay of Plenty Regional Council and E H Harrison and Royal Forest and Bird Protection Society of New Zealand Inc and B C Marshall and Whakatane Friends of Maruia and G J Dickson and Green Environmental Society v Whakatane District Council and Waimana 251/252 Trust		1										1	1							1		
W3/2002	A J Bell and W B Brabant and T and M Riley v Tasman District Council		1								1		1	1								1	
C97/04	G Bolton, C.J. Harley and K H Lucas (as trustees of the estate of G P Dixon) and J G Dixon v The Nelson City Council	1											1	1			1						1
W20/97	S J Browning v Marlborough District Council and New Zealand Marine Farming Association						1						1		1	1	1					1	
A66/2002	R Buchanan and Director-General of Conservation v Northland Regional Council and						1						1		1	1	1				1		
W70/99	Chance Bay Marine Farms v Marlborough District Council						1				1		1		1	1						1	
AP210/99	Chance Bay Marine Farms v Marlborough District Council						1				1		1		1	1				1			
W77/06	J Chapple, Nga Tangata Ahi Kaa Roa O Maketu, D Dinsdale v Bay of Plenty Regional Council Operations Group v Bay of Plenty regional Council and Rotorua District Council									1				1	1	1	1	1				1	
W64/96	A R Clyma, K W Braid, Globe Export Fisheries Ltd.J Todd, I L and K Weatherall, C Reid, Environment Access Inc, E Petersen v Otago Regional Council and Dunedin City Council, Port Chalmers Yacht Club, Terr-Nova Monowai sea Scouts							1					1	1	1	1		1	1			1	
C8/97	J Crooks & Sons v Invercargill City Council and Southland Regional Council				1								1	1			1						1
W187/96	Di Andre Estates Limited v Rodney District Council	1											1	1				1				1	
A24/94	Minister of Conservation and Waikanae District Progressive and Ratepayers Association and F Boffa and Kapiti Environmental Action Inc v Kapiti Coast district Council	1											1	1				1			1		
A024/2006	Director General of Conservation and Landco Ltd and MJ Dunn v Whangarei District Council		1								1		1	1							1		
A67/03	Director General of Conservation and A W Smith & others v Hurunui District Council and RG Foster			1									1	1				1			1		
W89/97	Director General of Conservation v Marlborough District Council and Marlborough Mussel Company Ltd						1						1		1	1	1					1	
C126/2002	The Doves Bay Society Inc and Kerikeri Cruising Club & Kerikeri Cruising Marina Ltd v Northland Regional Council , Far North District Council and Kerikeri Cruising Club & Kerikeri Cruising Marina Ltd							1					1	1	1	1	1		1				1
W69/05	Elkington Family Trust v Marlborough District Council						1						1		1	1		1				1	
C159/04	D N Ericsson & P J C Trotman v Dunedin City Council			1									1	1				1					1
A147/2004	Eyres Eco-Park Ltd v Rodney District Council	1											1	1				1			1		
W46/97	First Wave Ltd v Marlborough District Council						1						1		1	1	1					1	
A32/94	K Fortzer & N Ngawaka v Auckland Regional Council						1						1		1	1		1			1		
A166/2004	Freda Pene Reweti Whanau Trust v Auckland Regional Council						1						1		1	1	1				1		
W90/04	Gannet Beach Adventures Ltd and C Gordon and P A Nee Harland v Hastings District Council and Cape Kidnappers Station Ltd			1									1	1				1				1	
A148/2005	Genesis Power Ltd and The Energy Efficiency and Conservation Authority v Franklin District Council			1									1	1			1				1		
W29/93	J O and H J Gill and others v The Rotorua District Council and P Schwanner		1									1		1				1				1	
W42/2001	Golden Bay Marine Farmers, W J Wallace, Challenger Scallop Enhancement Company Ltd, First Wave Ltd, New Zealand Marine Farming Association, Ngati Tama Manawhenua Ki Te Tau Ihu Trust v Tasman District Council										1												
W19/2003	Golden Bay Marine Farmers, W J Wallace, Challenger Scallop Enhancement Company Ltd, First Wave Ltd, New Zealand Marine Farming Association, Ngati Tama Manawhenua Ki Te Tau Ihu Trust v Tasman District Council																						
W17/95	Greenshill v Waikato Regional Council						1						1		1	1						1	
A188/05	Gulf District Plan Association v Auckland City Council		1										1	1				1			1		
W17/2006	Harris v Tasman District Council			1									1	1								1	
W42/93	P J Harrison & Te Runganui o te tau ihu o waka a Maui & Minister of Conservation v Tasman District Council			1									1	1								1	

319

W30/05	P Horn v Marlborough District Council & S Hebberd	1											1	1				1				1	
C10/05	Infinity Group v Queenstown Lake District Council		1								1			1									1

Summary of court decisions where natural ch

Decision name	Applicant appeal council decision	Others appeal council decision	Provision/ Development approved	Reduced development approved	Applicant to submit revised proposal	Development declined	decision confirmed	Council decision	character physical	character ecological	Natural character visual	Court intent A	Court intent B	Court intent C	Court intent D	Court intent E1	Court intent E2	Court intent E3	Court intent F1	Court intent F2	Court intent F3	Court intent G1
Adventure Specialities Trust v Whangarei District Council	1			1				1		1	1								1			
Aqua King Ltd (Anakoha Bay) v Marlborough District Council	1					1	1				1	1										
Aquamarine Ltd v Southland Regional Council	1					1	1				1			1								
Arrigato Investments and Evensong Enterprises Ltd v Rodney District Council, Aukland Regional Council	1		1					1	pt	pt	1									1		
Arrigato Investments and Evensong Enterprises Ltd v Rodney District Council, Aukland Regional Council							n/a															
Ashton, T.F. v Rodney District Council	1			1				1			1								1			
Auckland Volcanic Cones Society Incorporated & Greenbelt Incorporated & others v Transit New Zealand		1	1				1			pt	pt						1					
Bay of Plenty Regional Council and E H Harrison and Royal Forest and Bird Protection Society of New Zealand Inc and B C Marshall and Whakatane Friends of Maruia and G J Dickson and Green Environmental Society v Whakatane District Council and Waimana 251/252 Trust		1			1			1			1								1			
A J Bell and W B Brabant and T and M Riley v Tasman District Council	?			1				ame nd			1								1			
G Bolton, C.J. Harley and K H Lucas (as trustees of the estate of G P Dixon) and J G Dixon v The Nelson City Council	1			1				1			1										1	
S J Browning v Marlborough District Council and New Zealand Marine Farming Association		1				1		1			1	1										
R Buchanan and Director-General of Conservation v Northland Regional Council and		1	1				1			pt	1					1						
Chance Bay Marine Farms v Marlborough District Council	1					1	1			pt	1											1
Chance Bay Marine Farms v Marlborough District Council	1					1	1															1
J Chapple, Nga Tangata Ahi Kaa Roa O Maketu, D Dinsdale v Bay of Plenty Regional Council Operations Group v Bay of Plenty regional Council and Rotorua District Council		1	1				1			pt						1						
A R Clyma, K W Braid, Globe Export Fisheries Ltd.J Todd, I L and K Weatherall, C Reid, Environment Access Inc, E Petersen v Otago Regional Council and Dunedin City Council, Port Chalmers Yacht Club, Terr-Nova Monowai sea Scouts		1				1		1	1	1	1	1										
J Crooks & Sons v Invercargill City Council and Southland Regional Council	1		1					1	pt	pt	1							1				
Di Andre Estates Limited v Rodney District Council	1		1					1												1		
Minister of Conservation and Waikanae District Progressive and Ratepayers Association and F Boffa and Kapiti Environmental Action Inc v Kapiti Coast district Council		1				1		1	pt		1	1										
Director General of Conservation and Landco Ltd and MJ Dunn v Whangarei District Council				1			?															1
Director General of Conservation and A W Smith & others v Hurunui District Council and RG Foster		1				1		1			1	1										
Director General of Conservation v Marlborough District Council and Marlborough Mussel Company Ltd		1				1		1	1	1	1	1										
The Doves Bay Society Inc and Kerikeri Cruising Club & Kerikeri Cruising Marina Ltd v Northland Regional Council , Far North District Council and Kerikeri Cruising Club & Kerikeri Cruising Marina Ltd	?		1				1		1	pt						1						
Elkington Family Trust v Marlborough District Council	1					1	1			1	1	1										
D N Ericsson & P J C Trotman v Dunedin City Council	1?					1					1	1										
Eyres Eco-Park Ltd v Rodney District Council	1				1						1									1		
First Wave Ltd v Marlborough District Council	1					1	1			1	1	1										
K Fortzer & N Ngawaka v Auckland Regional Council	1		1					1										1				
Freda Pene Reweti Whanau Trust v Auckland Regional Council	1					1	1				1	1										
Gannet Beach Adventures Ltd and C Gordon and P A Nee Harland v Hastings District Council and Cape Kidnappers Station Ltd		1				1		1			1	1										
Genesis Power Ltd and The Energy Efficiency and Conservation Authority v Franklin District Council	1		1					1			1						1					
J O and H J Gill and others v The Rotorua District Council and P Schwanner		1				1		1		1	1		1									
Golden Bay Marine Farmers, W J Wallace, Challenger Scallop Enhancement Company Ltd, First Wave Ltd, New Zealand Marine Farming Association, Ngati Tama Manawhenua Ki Te Tau Ihu Trust v Tasman District Council	1			?				?														1
Golden Bay Marine Farmers, W J Wallace, Challenger Scallop Enhancement Company Ltd, First Wave Ltd, New Zealand Marine Farming Association, Ngati Tama Manawhenua Ki Te Tau Ihu Trust v Tasman District Council																						
Greenshill v Waikato Regional Council		1				1		1			1	1										
Gulf District Plan Association v Auckland City Council		1				1		1			1		1									
Harris v Tasman District Council		1	1				1			1								1				
P J Harrison & Te Runganui o te tau ihu o waka a Maui & Minister of Conservation v Tasman District Council		1				1		1				1										
P Horn v Marlborough District Council & S Hebberd		1	1								1							1				
Infinity Group v Queenstown Lake District Council	1	1				1		1			1	1										

Decision number	Decision name	Rural /Lifestyle subdivision	Residential subdivision	Buildings & structures	Quarry/mining	Other terrestrial	Marine farms	Marinas /ports	Jetties/wharves	Other aquatic	Plan provisions excluding designations	Requirement	Coastal environment	Terrestrial	Aquatic	Water surface	Discretionary activity	Non complying activity	RCA	High Court or Court of Appeal	EC Auckland	EC Wellington	EC Christchurch
C77/2004	Jackson Bay Mussels Limited v The West Coast Regional Council						1						1		1	1	1						1
A72/98	Judges Bay Residents Association v Auckland Regional Council and Auckland City Council							1					1	1	1	1			1		1		
A152/02	W C Kalkman & V P Kalkman v The Thames Coromandel District Council & Puriri Valley Chalets Ltd			1									1	1				1			1		
A60/02	Kapiti Environmental Action Inc, M Wood, L Manning v The Kapitit Coast District Council & Pukenamu Estates Ltd	1											1	1				1			1		
A60/04	V and C A Kerr Trusts and W M G Yovich v Whangarei District Council			1							1		1	1							1		
W37/05	Kuku Mara Partnership (Admiralty Bay West)(Admiralty Bay East) v Marlborough District Council						1						1		1	1		1				1	
W25/2002	Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council						1						1		1	1		1				1	
W39/04	Kuku Mara Partnership & Friends of Nelson Haven and Tasman Bay (Inc) and JGM Ltd & Marborough Environment Centre & Sealord Shellfish Ltd v Marlborough District Council						1						1		1	1		1				1	
A73/2000	Kotuku Parks Ltd & Kapiti Environmental Action Inc & Waikanae Estuary Guardians & Te Runanga o Ati Awa ki Whakarongatai Inc v Kapiti Coast District Council		1										1	1			1				1		
W81/2001	J H King-Turner v Marlborough District Council						1						1				1					1	
A86/93	Lambly & Lambly v Whangarei District Council			1									1	1				1			1		
A126/06	Living Earth Ltd v Auckland Regional Council & Manukau City Council					1							1	1				1			1		
W45/2001	Lowry Bay Residents Association & Eastern Bays Little Blue Penguin Foundation Inc v Hutt City Council & Wellington Regional Council & Eastern Bays Little Blue Penguin Foundation			1									1	1				1				1	
A21/94	J D Lowe & another v Auckland Regional Council						1						1		1	1		1			1		
C121/2002	MacDonald V Christchurch City Council					1					1			1									1
W12/98	Marlborough Seafoods Limited v Marlborough District Council						1						1		1	1	1					1	
W23/03	S Martin-Weber and S Martin-Weber v Hutt City Council and Jourdan Developments Limited		1										1	1			1					1	
A69/95	Mataka Station Ltd v Far North District Council & Trustees of Matoa Block			1									1	1			1				1		
A24/94	Minister of Conservation and Waikanae District Progressive and Ratepayers Association and F Boffa and Kapiti Environmental Action Inc v Kapiti Coast District Council	1											1	1				1			1		
A19/94	Minister of Conservation v Whangarei District Council & F Visser	1											1	1				1			1		
W10/2006	The Matukituki Trust v Queenstown Lakes District Council			1										1			1					1	
A133/2003	M J Murphy v Rodney District Council	1											1	1				1			1		
W98/95	Nelson Fisheries Ltd v Marlborough District Council & Port Mussel Company Ltd						1						1		1	1		1				1	
W71/2005	M Newman-Hall, L Newman-Hall, JA Reader, G Cooper V Marlborough District Council & RPJ and MJ Gibson	1											1	1				1				1	
A95/2000	Ngati Kahu Ki Whangaroa Co-operative Society Limited & others v The Northland Regional Council & M Hemi and Muri-Tai Tio Limited						1						1		1	1	1				1		
W129/97	New Zealand Marine Hatcheries (Marlborough) Ltd v Marlborough District Council			1									1	1				1				1	
C36/93	New Zealand Rail Ltd v Marlborough District Council and Port Marlborough Ltd							1					1	1	1			1				1	
AP169/93	New Zealand Rail Ltd v Marlborough District Council and Port Marlborough Ltd							1					1	1	1			1		1			
W38/2006	New Zealand Shipping Federation of New Zealand, Strait Shipping Limited, Toll New Zealand Consolidated Limited v Marlborough District Council									1	1		1		1	1						1	
W7/94	Ngatiwai Trust Board v Whangarei District Council (Whananaki North campground)			1									1	1			1				1		
A80/95	Ngatiwai Trust Board v Whangarei District Council (Pataua South campground)			1									1	1			1				1		
A128/06	Northland Regional Council v Far North District Council	1									1		1	1							1		
A136/02	The Ohope Beach Development Society Incorporated v The Whakatane District Council & McBaco Holdings Limited			1									1	1			1				1		
A105/01	O'Shea v Auckland City Council	1											1	1				1			1		
C86/2000	Pacific Investment Trust v Banks Peninsula District Council			1									1	1				1					1
A77/95	Paihia and District Citizens Association Incorporated v The Northland Regional Council & DS Follett & MH Follett								1				1		1	1					1		
A135/2000	JW Patterson & Sons Ltd, Pukehina Beach Ratepayers Association Inc & Western Bay of Bay of Plenty District Council v Bay of Plenty Regional Council				1								1	1	1						1		
A8/99	GA Paykel and others, DL Nathan and others & Oyster Cove Limited v Northland Regional Council and Far North District Council			1					1				1	1	1	1	1				1		
C32/99	Pigeon Bay Aquaculture Ltd v A S Hay and others v Canterbury Regional Council						1						1		1	1	1						1
C179/2003	Pigeon Bay Aquaculture Ltd v Canterbury Regional Council						1						1		1	1	1						1
W51/06	Rahotia Marine Farms Limited and Elaine Bay Aquaculture Limited and A & R Bothwell and T & J Schwass v Marlborough District Council						1						1		1	1		1				1	
A125/98	Russell Protection Society Incorporated v Far North District Council & Pompallier Heights Ltd		1										1	1				1			1		
W75/05	REM Developments Limited v Rodney District Council			1					1				1	1	1	1	1					1	
A31/96	Reynolds v Kaipara District Council			1									1	1			1				1		
C106/2002	Sanford (South Island) Ltd v Southland Regional Council						1						1		1	1	1						1

Decision name	Applicant appeal council decision	Others appeal council decision	Provision/ Development approved	Reduced development approved	Applicant to submit revised proposal	Development declined	decision confirmed	Council decision	character physical	character ecological	Natural character visual	Court intent A	Court intent B	Court intent C	Court intent D	Court intent E1	Court intent E2	Court intent E3	Court intent F1	Court intent F2	Court intent F3	Court intent G1
Jackson Bay Mussels Limited v The West Coast Regional Council	1		1					1		1	1										1	
Judges Bay Residents Association v Auckland Regional Council and Auckland City Council		1	1				1			1	1							1				
W C Kalkman & V P Kalkman v The Thames Coromandel District Council & Puriri Valley Chalets Ltd		1				1		1							1							
Kapiti Environmental Action Inc, M Wood, L Manning v The Kapitit Coast District Council & Pukenamu Estates Ltd		1				1		1			1	1										
V and C A Kerr Trusts and W M G Yovich v Whangarei District Council	1		1					1										1				
Kuku Mara Partnership (Admiralty Bay West)(Admiralty Bay East) v Marlborough District Council	1					1					1	1										
Kuku Mara Partnership (Forsyth Bay) v Marlborough District Council	1					1			1	1	1	1										
Kuku Mara Partnership & Friends of Nelson Haven and Tasman Bay (Inc) and JGM Ltd & Marborough Environment Centre & Sealord Shellfish Ltd v Marlborough District Council	1	1				1		1	1	1	1	1										
Kotuku Parks Ltd & Kapiti Environmental Action Inc & Waikanae Estuary Guardians & Te Runanga o Ati Awa ki Whakarongatai Inc v Kapiti Coast District Council	1	1				1		1	1		1		1									
J H King-Turner v Marlborough District Council	1					1					1	1										
Lambly & Lambly v Whangarei District Council		1				1		1			1				1							
Living Earth Ltd v Auckland Regional Council & Manukau City Council	1		1					1			1					1						
Lowry Bay Residents Association & Eastern Bays Little Blue Penguin Foundation Inc v Hutt City Council & Wellington Regional Council & Eastern Bays Little Blue Penguin Foundation		1				1		1			1		1									
J D Lowe & another v Auckland Regional Council	1					1					1	1										
MacDonald V Christchurch City Council		1		1			1			1												1
Marlborough Seafoods Limited v Marlborough District Council	1					1	1			1	1	1										
S Martin-Weber and S Martin-Weber v Hutt City Council and Jourdan Developments Limited		1	1								1									1		
Mataka Station Ltd v Far North District Council & Trustees of Matoa Block		1?	1								1									1		
Minister of Conservation and Waikanae District Progressive and Ratepayers Association and F Boffa and Kapiti Environmental Action Inc v Kapiti Coast District Council		1				1		1	pt		1	1										
Minister of Conservation v Whangarei District Council & F Visser		1				1		1			1	1										
The Matukituki Trust v Queenstown Lakes District Council	1					1	1		1	1	1	1										
M J Murphy v Rodney District Council	1					1	1				1				1							
Nelson Fisheries Ltd v Marlborough District Council & Port Mussel Company Ltd		1	1				1									1						
M Newman-Hall, L Newman-Hall, JA Reader, G Cooper V Marlborough District Council & RPJ and MJ Gibson		1	1				1											1				
Ngati Kahu Ki Whangaroa Co-operative Society Limited & others v The Northland Regional Council & M Hemi and Muri-Tai Tio Limited		1	1				1				1							1				
New Zealand Marine Hatcheries (Marlborough) Ltd v Marlborough District Council	1	1	1				1				1					1						
New Zealand Rail Ltd v Marlborough District Council and Port Marlborough Ltd		1		1			?										1					
New Zealand Rail Ltd v Marlborough District Council and Port Marlborough Ltd		1	1														1					
New Zealand Shipping Federation of New Zealand, Strait Shipping Limited, Toll New Zealand Consolidated Limited v Marlborough District Council			1				1		1	1												1
Ngatiwai Trust Board v Whangarei District Council (Whananaki North campground)		1	1				1									1						
Ngatiwai Trust Board v Whangarei District Council (Pataua South campground)		1	1				1				1					1						
Northland Regional Council v Far North District Council																						1
The Ohope Beach Development Society Incorporated v The Whakatane District Council & McBaco Holdings Limited		1			1						1										1	
O'Shea v Auckland City Council	1					1	1							1								
Pacific Investment Trust v Banks Peninsula District Council	1					1	1				1				1							
Paihia and District Citizens Association Incorporated v The Northland Regional Council & DS Follett & MH Follett		1	1				1				1							1				
JW Patterson & Sons Ltd, Pukehina Beach Ratepayers Association Inc & Western Bay of Bay of Plenty District Council v Bay of Plenty Regional Council	1	1	1				1									1						
GA Paykel and others, DL Nathan and others & Oyster Cove Limited v Northland Regional Council and Far North District Council	1	1		1			1	1			1										1	
Pigeon Bay Aquaculture Ltd v A S Hay and others v Canterbury Regional Council	1	1	1				1	1			1					1						
Pigeon Bay Aquaculture Ltd v Canterbury Regional Council	1			1				1		pt	1					1						
Rahotia Marine Farms Limited and Elaine Bay Aquaculture Limited and A & R Bothwell and T & J Schwass v Marlborough District Council	1	1	1				1	1			1							1				
Russell Protection Society Incorporated v Far North District Council & Pompallier Heights Ltd		1	1				1				1					1						
REM Developments Limited v Rodney District Council	1			1				1			1							1				
Reynolds v Kaipara District Council		1	1				1				1					1						
Sanford (South Island) Ltd v Southland Regional Council	1		1					1			1							1				

Decision number	Decision name	Rural /Lifestyle subdivision	Residential subdivision	Buildings & structures	Quarry/mining	Other terrestrial	Marine farms	Marinas /ports	Jetties/wharves	Other aquatic	Plan provisions excluding designations	Requirement	Coastal environment	Terrestrial	Aquatic	Water surface	Discretionary activity	Non complying activity	RCA	High Court or Court of Appeal	EC Auckland	EC Wellington EC	Christchurch
C50/02	Save The Bay Limited , O Snoep & Royal Forest & Bird Protection Society v Christchurch City Council [& Taylors Mistake Association Inc & Canterbury Regional Council]			1							1		1	1									1
A179/02	Scott v Whangarei District Council	1											1	1				1			1		
C60/05	J Skurr v Queenstown Lakes District Council and Upper Clutha Environmental Society Inc	1											1	1				1					1
A066/2006	Sea-Tow Limited & McCallum Bros Limited v Auckland Regional Council				1								1		1		1				1		
A045/2006	South Kaipara Harbour Environmental Trust & B Hietz & Royal Forest and Bird Protection Society Inc & Te Runanga o Ngati Whatua & Kakanui Marae Trust Board v Auckland Regional Council & Biomarine Limited						1						1		1	1	1				1		
W082/2007	Save the Point Inc & C Webster v Wellington City Council & Wellington Regional Council			1									1	1			1					1	
C191/04	PH, KM and FM Stapylton-Smith & OJ Rolton and J Miller v Banks Peninsula District Council & GA and LJ Mead	1											1	1				1					1
A108/2005	Tairua Marine Limited and Pacific Paradise Limited v Waikato Regional Council & Thames-Coromandel District Council							1					1	1	1	1	1	1	1		1		
CIV 2005-485-1490	Tairua Marine Limited and Pacific Paradise Limited v Waikato Regional Council & Thames-Coromandel District Council							1					1	1	1	1	1	1	1	1			
C6/2000	Tarawera Lakes Protection Society Incorporated v Rotorua District Council & TM and MB Peterson								1						1	1		1					1
A099/2004	Te Roopu Manaaki o Tarawera v Rotorua District Council		1								1			1							1		
W16/95	Thomas & Thomas v Marlborough District Council						1						1		1	1		1				1	
A100/2000	Transit New Zealand & MK Kett & WR Pond and D Andre v Auckland Regional Council					1							1	1	1		1				1		
W103/96	Trio Holdings & Treble Tree v Marlborough District Council						1						1		1	1						1	
W181/96	Brook Weatherwell-Johnson and others v Tasman District Council		1								1		1	1								1	
C66/2006	C White & CJ Barns & J and M Chetwin & NA Lockley & D and C Robertson v Waitaki District Council & Glanmor Developments Ltd		1										1	1				1					1
	Total	17	12	22	3	3	27	7	5	3	13	2	89	65	44	39	34	45	5	4	43	35	17

Decision name	Applicant appeal council decision	Others appeal council decision	Provision/ Development approved	Reduced development approved	Applicant to submit revised proposal	Development declined	decision confirmed	Council decision	character physical	character ecological	Natural character visual	Court intent A	Court intent B	Court intent C	Court intent D	Court intent E1	Court intent E2	Court intent E3	Court intent F1	Court intent F2	Court intent F3	Court intent G1
Save The Bay Limited , O Snoep & Royal Forest & Bird Protection Society v Christchurch City Council [& Taylors Mistake Association Inc & Canterbury Regional Council]				1			1											1				
Scott v Whangarei District Council	1		1					1			1					1						
J Skurr v Queenstown Lakes District Council and Upper Clutha Environmental Society Inc	1					1	1				1	1										
Sea-Tow Limited & McCallum Bros Limited v Auckland Regional Council	1		1					1	1	1								1				
South Kaipara Harbour Environmental Trust & B Hietz & Royal Forest and Bird Protection Society Inc & Te Runanga o Ngati Whatua & Kakanui Marae Trust Board v Auckland Regional Council & Biomarine Limited		1				1		1		1	1	1										
Save the Point Inc & C Webster v Wellington City Council & Wellington Regional Council		1				1		1			1	1										
PH, KM and FM Stapylton-Smith & OJ Rolton and J Miller v Banks Peninsula District Council & GA and LJ Mead		1				1		1		1	1	1										
Tairua Marine Limited and Pacific Paradise Limited v Waikato Regional Council & Thames-Coromandel District Council	1					1	1		1	1	1	1										
Tairua Marine Limited and Pacific Paradise Limited v Waikato Regional Council & Thames-Coromandel District Council	1					1																
Tarawera Lakes Protection Society Incorporated v Rotorua District Council & TM and MB Peterson		1	1				1			1	1					1						
Te Roopu Manaaki o Tarawera v Rotorua District Council																						1
Thomas & Thomas v Marlborough District Council	1					1	1				1		1									
Transit New Zealand & MK Kett & WR Pond and D Andre v Auckland Regional Council	1	1	1				1				1						1					
Trio Holdings & Treble Tree v Marlborough District Council	1			1				1 pt	1	1	1								1			
Brook Weatherwell-Johnson and others v Tasman District Council		1				1		1			1	1										
C White & CJ Barns & J and M Chetwin & NA Lockley & D and C Robertson v Waitaki District Council & Glanmor Developments Ltd		1				1		1			1				1							
Total	48	51	36	12	3	45	39	44	11	21	30	30	5	2	5	15	5	14	5	5	4	8

Appendix 4: Natural character assessment form

Location **Date** **Assessor** **Field check?**

Code				
Completed?				
Environ type				
Site summary				
Cover NA 1				
Cover NA 2 or BAA				
Present Potential cover				
P to PPC NA1				
P to PPC NA2				
P to PPC BAA				
Pest control				
Harvest control				
% area NA1				
% area NA2				
% area BAA				
% area Bldg				
% area Struc				
% area pave				
% area total				
Bldg max hgt				
Bldg colour				
Bldg reflect				
Bldg prom				
Struc mx hgt				
Struc colour				
Struc reflect				
Struc prom				
HG changes (number)				
HG 1 mag				
HG 1 %A				
HG2 mag				
HG 2 %A				
HG 3 mag				
HG 3 %A				
Risk NN Sound				
Resil NN Sound				
Risk A light				

Appendix 5: Present-potential cover and succession trends for the coastal environment of eastern Northland, New Zealand

This Appendix provides the detail for determining *present potential cover* and the construction of the scoring tables for measuring *present potential cover* in Northland as discussed in Chapter 7.

Forest as present-potential cover

Leathwick (2001) identifies the potential forest of eastern Northland as primarily *Agathis- Beilschmedia* forests (a subset of conifer-broadleaved forests of warm climates). Rimu (*Dacrydium cupressinum*) was often associated with these kauri (*Agathis australis*) and taraire (*Beilschmedia taraire*) forests, commonly as a subdominant (Norton et al. 1988).

LENZ Level II classifies much of eastern coastal Northland south of Karikari Peninsula (and excluding the volcanic soils around Kerikeri) as Environment A6 Leathwick et al (2003). The original vegetation for this Environment was kauri and its associated species on infertile hill crests and upper slopes. On mid-slopes there were rimu, miro (*Prumnopitys ferruginea*), totara (*Podocarpus totara*), northern rata (*Meterosideros robusta*), tawa (*Beilschmedia tawa*), taraire, kohekohe (*Dysoxylum spectabile*) and nikau (*Rhopalostylis sapida*). These graded into kahikatea (*Dacrycarpus dacrydioides*), matai (*Prumnopitys taxifolia*), puriri (*Vitex lucens*) and pukatea (*Laurelia novae-zelandiae*) on lower slopes and valley floors. Pohutukawa (*Meterosideros excelsa*) established on steep coastal slopes with smaller trees such as taraire and mageao (*Litsea calicaris*) underneath. Mangroves were common on the coastal margins (Leathwick et al. 2003).

Some of the steeper coastal headlands (including Cape Brett, parts of the open coast between Whangaroa Harbour and Berghan Point north of Mangonui Harbour) are within LENZ Level II category D1. D1 includes most of the remaining kauri stands on leached upland soils. On lower slopes kauri was present and species such as kohokohe, puriri, pukatea and kahikatea occurred in sites of higher fertility (Leathwick et al. 2003). Environment D1 is widely distributed in the upper north Island and includes upland sites.

Less than 0.5% of the original mature kauri forest remains (Froude et al. 1985), and virtually none is in the coastal environment. Very limited areas of mature coastal podocarp forest remain, primarily as scattered remnants of kahikatea forest or mixed podocarp/ mixed broadleaved forest in valley bottoms. In some locations where the present-potential cover is forest, the time since disturbance has not been sufficiently long to permit the development of native conifer/mixed broadleaved forest. For example, on some areas of duneland the present-potential cover is kanuka forest (Lux et al. 2006). On very exposed coastal sites it is likely that the present-potential cover is mixed broadleaved forest often dominated by pohutukawa (Conning & Miller 1999).

Non-forest present-potential-cover for terrestrial environments

For some terrestrial parts of the eastern Northland coastal environment the present-potential cover is not forest. These areas are primarily where:

- there is a new surface (e.g. recent dune surface, a recent natural landslide, unweathered surface rock); or
- the geomorphology and hydrological regime has created conditions suitable for non-forested wetlands; or
- high levels of saltwater inundation or spray prevent the establishment of forest; or
- steep rocky coastal cliffs mitigate against the establishment of forest

The assessment of the spatial pattern of present-potential cover for dunes is more complex, and therefore more difficult, than for many other terrestrial environments. This is because present-potential cover is the cover that would be present today had humans and the introduced species they brought with them not disturbed the natural cover. In dune systems this follows a sequence based on the amount of time an area has been stable (with the associated soil development and vegetation succession) and the local geomorphological and hydrological patterns (determining the positions of dune lakes and dune swales or wetlands).

Heading inland from mean high water springs, present-potential cover on the dune system of eastern Northland from Marsden Point to Waipu Cove is:

- A limited area of un-vegetated sand, especially near river mouths
- Native sand binders on the foredune and sites of recent natural dune blow-outs
- Native scrub including *Coprosma acerosa* and pohuehue (*Muehenbeckia complexa)* and manuka
- Native forest dominated by local variety of kanuka (*Kunzea ericoides var linaris*)
- On the older consolidated dune ridges the present-potential vegetation cover pattern is probably mature mixed broadleaved native forest including the podocarp totara (based on current regeneration trends). In the south where the dunes are closer to steeper coastal cliffs pohutukawa is likely to be a prominent component (Lux et al. 2006)
- Lower lying ephemeral wetlands (Johnson & Gerbeaux 2004), or swales, occur between dunes. Depending on their location the present-potential cover is typically turf and sward and sometimes rushland and scrub (Johnson & Gerbeaux 2004). In the past there was a series of dune swales with a flax, rush and reed cover, and dune lakes along the Marsden Point/Waipu Cove coast. Today only one natural (although highly modified) dune lake remains in this area (Lux et al. 2006)).

On dunelands there is a transition zone between areas where present-potential cover is native sand-binders, and areas where present-potential cover is mature forest. Transition zone width varies depending on the probability of natural periodic disturbance. It can be extremely narrow (e.g. the abrupt transition from mature podocarp/mixed broadleaved forest to exposed sandy beach found in some parts of southern Westland and the southern Catlin coast). This zone is much wider where a coast is subject to regular cycles of erosion and deposition due to cyclical weather patterns and/or periodic tsunamis (e.g. Bay of Plenty). There has been considerable modification to the hydrology and geomorphology of many dunelands. Protocols for addressing this disturbance have been developed (Table 7.1).

Coastal cliffs and rocky coastal margins are examples of small scale terrestrial environments where present-potential cover is not tall native conifer/ mixed broadleaved forest. Vegetation on coastal cliffs is typically of low stature because of climate, topography and skeletal soils. The vegetation on exposed rocky coastal margins is subject to extreme conditions including salt spray, strong winds and skeletal soils. Few species are able to tolerate these conditions.

Present-potential cover will vary depending on site conditions, type of disturbance that reset succession and the elapsed time since the last major disturbance. In coastal Northland the succession start point is typically bare surface or poor quality "pasture" dominated by introduced species. Native species that are able to grow here, especially initially, include pohutukawa, flax, and taupata (*Coprosma repens*). The progression in the height, and especially the spread of pohutukawa, provides an indication of vegetation development in this type of environment. Steep rock faces with native grasses, mountain flax and *Astelia banksii* can occur naturally.

Present-potential-cover for freshwater wetlands

Less than 10 percent of the New Zealand wetland area present in 1850 remains today (Cromarty & Scott 1996) and what remains is often scattered and fragmented. Prior to European settlement, wetlands in most lowland alluvial plains draining into estuaries and harbours were typically swamps (using the terminology of Johnson & Gerbeaux (2004)), adjoining the water course. Swamps receive a relatively rich supply of nutrients and sometimes sediment (via runoff) and groundwater from nearby land.

Many wetlands have a relatively short natural lifespan (hundreds or thousands of years), with human disturbance through drainage, supply of excessive nutrients and sedimentation accelerating the natural processes of drying and infilling (Sorrell & Gerbeaux 2004). This creates particular challenges for determining present-potential cover.

Former wetland sites that have been subject to on-site drainage activities would retain a present-potential cover of some type of wetland vegetation (Table 7.1). On-site drainage is potentially reversible. The type of wetland vegetation present in a particular location depends primarily on hydrology (depth of water, frequency of inundation, and wetting and drying cycles), and nutrient availability (Sorrell & Gerbeaux 2004). Where water is deep and stable the most flood-tolerant species predominate –typically raupo (*Typha orientalis*) or club rush (*Schoenoplectus tabernaemontani*). Depending on the level of inundation, some *Carex* and rush species may also be present. Where the wetlands are on saturated soils or only periodically inundated soils there is usually a more diverse range of species, particularly where water levels fluctuate but only over a moderate range. Wetlands dominated by *Juncus*, *Carex* and *Baumea* typically occur where water is close to the surface for much of the time with only short periods of inundation or water a few millimetres below the surface (Sorrell et al. 2004).

Prior to European settlement many alluvial plain wetlands were a complex pattern of open water (sometimes flowing), permanently wet areas and areas that were temporarily flooded. Kahikatea dominant forest was typically found in temporarily flooded areas and is likely to be the present-potential cover for areas subject to periodic flooding of previously unconstrained water bodies, especially rivers. A mixture of flax (*Phormium tenax*), manuka, Coprosma scrub species, Carex species, rushes and reeds were found in permanently wet areas. In low gradient areas, especially adjoining the transition from saltmarsh to freshwater wetland, the present-potential cover is likely to include combinations of flax, scrub (often manuka and *Coprosma* species), rush and sedge vegetation.

The challenge is to determine the present-potential cover for a particular area of current or former wetland. Assessments of present-potential cover should consider the likely natural hydrological regime and use that as a basis for estimating likely present-potential cover. As long as the assessments are clearly documented, the estimated present-potential cover can be modified later if more detailed information becomes available.

Present-potential-cover for the marine soft sediments

This section addresses the cover for intertidal and shallow subtidal (<35m) soft sediments. Present-potential cover is discussed in broad categories: mangrove forest and scrub; saltmarsh; seagrass meadows and other soft-sediment covers. Deep soft-sediments are not addressed in this paper.

Mangrove forest and scrub

Determining the extent and characteristics of mangrove forest and scrub present-potential cover in eastern Northland intertidal sheltered waters requires analysis of mangrove growth forms and heights along with the characteristics of the physical environment. The New Zealand mangrove (*Avicennia marina* subsp *australasica*) is a small evergreen tree or shrub that often forms dense stands along sheltered intertidal margins of low energy coastal environments north of latitude 38 deg S. While its size and growth form can vary considerably (Beard 2006) its average height is greatest in northern New Zealand. At its southern limit the New Zealand mangrove exists only in shrub form.

De Lange and de Lange (1994) found no systematic trends in maximum mangrove size and distinguished three growth forms including a form that was significantly taller than average at about 10m tall and often forming an incomplete cover. Larger trees are more common on the outer margins of mangrove systems and the borders of streams where there is favourable drainage (Dingwall 1984). In the Firth of Thames Swales et al. (2007) found that in the mangrove belt established since 1952 mangrove height ranged from 0.5 to 3.5m without any obvious relationship to distance from shore or porewater salinity. They distinguished between open branching forms where the trees had grown in high light environments and very straight trunks of those growing in competition for light. Mom (2005) developed pictorial models for mangrove locations where there were low levels of sedimentation, and high levels of sedimentation where mangroves were either infilling (increasing density) or extending their range. While mangroves are found preferentially on soft muddy waterlogged sediment they can grow on other substrates (Beard 2006).

Eastern Northland harbours and estuaries typically contain extensive areas of mangroves, often of varying sizes. Several trends have influenced the present-day extent and density of mangroves in eastern Northland:

- Considerable areas of mangrove were infilled for agricultural and other purposes. This mostly occurred prior to the first aerial photographs and the area involved is unknown (Morrisey et al. 2007)
- The amount of sediment reaching most Northland harbours and estuaries, the proportion that is in the smaller size classes and the actual estuary sedimentation levels have increased greatly since human (especially European) settlement (Morrisey et al. 2007). In the Coromandel Hume and Dahm (1992) found current estuarine sedimentation rates to be at least 3-5 times higher than those prior to European settlement and, in some locations with very low background estuarine sedimentation rates, those rates increased by up to 25-45 times
- Rate changes for sedimentation rates can be location specific. For example, rates in the Rotokakahi Tributary of the Whangape Estuary in western Northland were found to have increased by one hundred fold from 0.1mm/yr -0.5mm/year 1000 years ago, to 17-31mm/year over the last few centuries (Nichol et al. 2000). In contrast the sedimentation rates in the Awaroa Tributary of the same estuary had changed little over the same time
- The extent of mangroves is increasing in some locations. This is likely to be due to a combination of accelerated sedimentation, recovery after grazing and recovery in areas where mangroves were previously cut or cleared or the area drained. For the Whangape Estuary Mom (2005) found that the increase in mangroves in the Awaroa Tributary was due to mangroves recolonising an area that would have naturally been mangrove vegetation had humans not previously stop-banked and drained the area. With the cessation of stopbank maintenance mangroves quickly recolonised. In contrast the significant increase in mangroves in the Rotokakahi Tributary was the result of mangroves colonising a newly-created series of shoals in the main channel These shoals were the result of catchment-derived high sediment loads in the Rotokakahi Tributary (Creese et al. 1998)

- In some estuaries there has been little change in mangrove extent ,especially where mangrove spread is restricted by the low tide channel on the seaward edge and inland by elevation changes (Morrisey et al. 2007) or there has been little change to background sedimentation rates (e.g. Tauhoa Reserve in Kaipara Harbour (Mom 2005))
- Structures such as road and rail causeways in harbours and estuaries change water circulation and velocity patterns, leading to areas of increased sedimentation where water velocity is decreased and scouring where water flows are increased by constriction. A review of New Zealand causeway crossings including a detailed assessment of 15 within the distribution range of mangroves found that in some cases there was a slight increase in mangrove density but little change in total area while in others there was a substantial increase in mangroves (sometimes matching increases elsewhere in the estuary) (Roper et al. 1993). They also found that mangroves frequently colonised the embankment

Mangroves enhance sediment accretion and the highest sedimentation rates are usually on the seaward fringe or along tidal channels (Morrisey et al. 2007). It has not been resolved whether mangroves form a steady-state system or whether they are eventually replaced by different (probably terrestrial) habitats. There is little evidence that they spread up into saltmarsh unless the saltmarsh has been damaged by for example, vehicle tracks (Morrisey et al. 2007). While the extent of seagrass is typically diminishing in estuaries where mangroves are increasing, those diminishing seagrass beds have been adversely affected by high concentrations of suspended and deposited sediment (Morrisey et al. 2007). Morrisey et al. (2007) noted that the environmental effects of mangrove removal (including the effect on fine sediment dispersal) are poorly known.

A study of two embayments in Tauranga Harbour found sedimentation rates up to 21mm/yr under mangroves, but also found sedimentation on bare flats in front of the mangroves (Stokes et al. 2009b). This meant that the mangroves were not the sole drivers of topographic change. An assessment in another estuary within Tauranga Harbour found that sediment elevation decreased where mangroves had been removed, although it was not clear how much was due to the decomposition of roots versus sediment removal. After 18 months the mean sediment particle size on the bare mangrove site had increased but was still finer than that found on the bare flats (Stokes et al. 2009a). More time is needed to determine long-term trends.

In light of the above, it is suggested that mangroves form the present-potential cover in locations where they currently occur, and where they have been removed from a site by clearance, drainage or similar. Human-induced accelerated sedimentation rates and changes in sedimentation deposition patterns can be directly addressed by the hydrological and geomorphological naturalness parameters and present-potential cover reset to reflect the changed conditions (Table 7.1). Mangrove community structure (using the vegetation structure classification of Atkinson (1985)) and density can be used to refine present-potential cover assessments.

Saltmarsh

As saltmarshes establish in substrates and hydrological regimes that are similar to those where mangroves are found, their relative extent in Northland is more limited than for more southern estuaries where mangroves have less vigour or are absent due to temperature limitations. Typically saltmarshes in Northland occur upstream and/or inland of mangrove forests in areas of very gradual topography. They are usually absent where the topography landward of the estuarine coast is anything other than gentle.

There are very limited areas of saltmarsh on open Northland coasts. These areas are usually where there is a barrier providing protection that allows sufficient sedimentation for saltmarsh to establish.

Chapman (1976) discusses North Atlantic seral pathways that begin with saltmarsh. New Zealand's uplift and sea level rise collectively mitigate against the ongoing sedimentation that eventually converts saltmarsh to dry land in parts of the North Atlantic. Some of the most effective saltmarsh plants for trapping sediment – species from the genus *Spartina* – are generally absent in New

Zealand. *Spartina* species are pest plants (Protect New Zealand 2002) that colonise intertidal environments trapping sediment to raise ground level above high tide so allowing a range of terrestrial (usually pest) plant species to establish (Craw 2000).

Saltmarsh in eastern Northland is typically dominated by rushes such as oioi (*Apodasmia similis*) and *Juncus krausii* as well as low shrubs such as marsh ribbonwood (*Plagianthus divaricatus*). It can transition to freshwater wetlands, typically swamps with species such as flax (*Phormium tenax*), raupo (*Typha orientalis*) and manuka (*Leptospermum scoparium*). In many areas these freshwater wetlands have been drained. In some areas the transition to dry land is through salt –tolerant manuka-dominant scrub.

It addition to its current locations saltmarsh is the present-potential cover for areas that have been actively drained and converted to other vegetation. Where the latter has occurred it may be difficult to identify the former inland boundary of saltmarsh, especially where there was a transition to freshwater wetland.

Sea grass meadows

New Zealand's sea grass species (*Zostera capricorni*) has a much higher light requirement than most sea grass species found overseas (Reed et al. 2005). It appears that the New Zealand species of *Zostera* may require up to 30-40% of incident irradiance on average over a year (Schwarz unpublished data reported in Reed et al (2005). This makes the New Zealand *Zostera* relatively sensitive to the effects of factors that lower water clarity. Subtidal beds are particularly susceptible.

Park (1999) found that the extent of subtidal sea grass beds in Tauranga Harbour in diminished by 90% from 1959 to 1996. This is the result of increased (especially fine) sediment associated with intensive rural and urban development in the catchment and the regular re-suspension of the fine sediments. In contrast, Whanganui Inlet in the north-western South Island has extensive intertidal and subtidal sea grass beds that do not appear to have diminished over the same period. The catchment of this large inlet is mostly in original native forest, the incoming waters are not stained with humic acids and the Inlet water clarity is high.

Hayward et al. (2001) found extensive beds of sea grass covering over half the area of Parengarenga Harbour in the Far North of Northland. Most was found growing on sandy substrate in the low intertidal, between mid and high tide. The only areas where sea grass was not well developed were the harbour entrance and the upper muddier arms of the Waiheuheu Arm. The North Island's west coast snapper fishery is now largely dependent on snapper from the Kaipara Harbour with its 15km^2 of largely intertidal sea grass meadows (Morrison et al. 2009). Human activities have led to the disappearance of the once extensive seagrass meadows of the Manukau Harbour and few snapper now come from this harbour (Morrison et al. 2009).

Clearance of the original native vegetation cover and past and present catchment land uses have increased the levels of sediment and nutrients being delivered to most Northland harbours and estuaries. These factors have led to often significant decreases water clarity and increases in fine sediment, thereby reducing the extent of suitable present day habitat for sea grass. Dredging and dumping have further reduced sea grass habitat. In the late 1960's 12-14km^2 of seagrass were destroyed in Whangarei Harbour in Northland by the deposition of 5 million tonnes of fine sediment from port expansion and the cement works (Morrison 2003).

Sea grass does not naturally occur in areas that are highly exposed to heavy surf and swell. It generally avoids very fine silt and mud substrates that can be resuspended, especially for subtidal beds. Some residual upper intertidal sea grass beds may remain as sediment particle size diminishes and water clarity decreases, provided the plants are able to get enough light while they are uncovered and do not suffer from summer desiccation.

Whanganui Inlet and Parengarega Harbour may provide indicative baselines on the likely historical extent of sea grass meadows. Catchment off-site impacts on water clarity and sedimentation reset present-potential cover (Table 7.1) and are addressed directly by the hydrological and geomorphological naturalness parameters. Present-potential cover is not reset for on-site activities such as dredging and dumping.

Other shallow soft –sediment covers

A variety of benthic communities are found on soft sediments in waters shallower than 35m. Many of these communities are highly vulnerable to and have been extensively damaged by human activities. It is difficult to predict present-potential cover in many locations given the lack of information about the spatial distribution of different subtidal benthic communities and the extent to which they have been damaged. Direct damage has come from dredging (method of bivalve harvest, creating navigation routes and for various infrastructure and commercial projects), trawling, anchoring and dumping. Benthic communities on soft sediments have also been adversely affected by sediment sourced from land use activities -both as a deposited layer and suspended in the water column thereby reducing light reaching the seabed (Morrison et al. 2009)

One example of the reduction in the extent of intact benthic communities of soft sediments is the green-lipped mussel reefs of the Firth of Thames. These reefs once covered extensive areas but overfishing using destructive techniques led to the end of the commercial fishery in the 1960's. McLeod (2009) found that the mussel reef community has the highest secondary productivity of any marine system yet recorded in New Zealand and that their former extent was so great that the historical reefs could have filtered the entire water volume of the Firth of Thames in less than a day. Today the remnant reefs would take nearly two years to filter the same amount of water. McLeod (2009) found that recruitment limitation was the likely reason for their lack of recovery.

Horse mussel beds are another benthic community of soft sediments. They are not usually harvested directly, but have been extensively damaged by those using destructive bottom fishing methods (e.g. dredging) for other benthic species. They are highly sensitive to sedimentation (Morrison et al. 2009) and are easily damaged by anchors.

Rhodolith beds are found in areas with higher currents and clear water. They are vulnerable to direct physical damage as well as habitat degradation (Morrison et al. 2009). Northland east coast locations include Urupukapuka Island in the Bay of Islands (Hayward et al. 1981) and the Cavali Islands (Grace & Hayward 1980). There are other communities each with their preferences for water clarity, currents and substrate sediment characteristics. Many bivalve species (e.g. scallops) prefer coarser sediments.

Studies such as the change in green-lipped mussels in the Firth of Thames (McLeod 2009) provide an indication of the scale of changes in some areas, especially those that were subject to intensive fishing using dredging and other destructive fishing techniques.. Catchment off-site impacts on water clarity and sedimentation do reset present-potential cover (Table 7.1) and are addressed directly by the hydrological and geomorphological naturalness parameters. Present-potential cover is not reset for on-site activities such as dredging and dumping.

Present-potential cover for shallow subtidal reefs

It is difficult to predict present-potential cover for shallow (<35m water depth) reefs. Patterns observed over a 25 year period in a large southern California *Macrocystis* kelp forest led Dayton et al. (1998) to suggest that the determination of a natural baseline was virtually impossible. This was because many large animals had been functionally removed for many years, kelps were sensitive to large scale low frequency shifts in conditions, and fishing was having a huge effect on abundance, size frequency and distribution of many species. In spite of these changes the plants often remained. They did, however, observe that kelp forests were uniquely vulnerable to being destroyed by a single herbivore- the sea urchin. This led to extensive bare areas that could persist for many years and only recovered when urchin numbers were significantly reduced by disease, predation or storms.

Several authors (Choat & Schiel 1982; Grace 1983) have discussed the typical shallow rocky zone dominated by kina (urchins) (*Evechinus chloroticus*) found on open rocky coasts of northern New Zealand. This zone ("urchin barrens") typically occurs between water depths of 3-6m and 8-10m (Grace 1983) although this can vary considerably. The "urchin barrens" zone does not contain tall brown algae species found above (typically dominated by fucoid species of the *Carpophyllum*, *Sargassum* genera) or below it (typically the laminarian *Ecklonia radiata*) (Choat & Schiel 1982). Grace (1983) observed that kina could spread into areas occupied by tall brown algae species and extend the "urchin barrens" zone considerably. He suggested that this expansion could be the result of large scale fishing pressure on kina predators -snapper (*Pagrus auratus*) and rock lobster (*Jasus edwardsii*).

Grace's suspicions were confirmed by Parsons et al. (2004) who repeated the marine habitat mapping at the no-take Cape Rodney – Okakari point (Leigh) Marine Reserve 22 years after the original mapping in 1978 (two years after the reserve's establishment). The most obvious change was the total disappearance of "urchin barrens" and the recovery of kelp forest in waters shallower than 8m. This was attributed to the recovery in the abundance and size of sea urchin predators, especially snapper (Willis et al. 2003) and rock lobster (Kelly et al. 2000), following the cessation of fishing. Parsons et al. (2004) observed that anecdotal reports collated by Dromgoole (1964) suggested that "urchin barrens" replaced kelp forest sometime after 1950 throughout much of the north-eastern North Island. They observed that this coincided with a sudden increase in snapper landings and a drop in spawning stock biomass reported by Gilbert et al. (2000). Social and historical research methods supplementing information gaps in the exploitative history of snapper (Parsons et al. 2009) found that snapper had been harvested since humans settled in New Zealand, with localised depletion beginning in the late nineteenth century and accelerating in the twentieth century with the lowest biomass being reached in the mid 1980's. This research strongly suggests that the "urchin barrens" present in rocky reef shallows in most of the north-eastern North Island is not the present-potential cover and so should be scored accordingly.

In addition to disappearance of "urchin barrens" at the Leigh Marine Reserve Parsons et al. (2004) also found reductions in the extent of tall brown algae *Ecklonia* and the sponge garden communities at depth. They considered that this could be the result of increased turbidity and sedimentation caused by terrestrial erosion and runoff and/or increased sand deposition in times of low surge. Schwarz et al. (2006) found that sediment reduced the growth of *Ecklonia* and significantly reduced the epifauna (responsible for 80% rocky reef animal productivity) associated with *Ecklonia*. Prolonged phytoplankton blooms (resulting from increased nutrient levels) can also lead to substantial mortality of *Ecklonia,* especially at depth (Cole & Babcock 1996). The adverse effects sedimentation and reduced water clarity caused by terrestrial land use activities on a variety of reef-forming organisms can be major (Morrison et al. 2009). These "off-site" effects are addressed through the hydrological and geomorphological parameters and the present-potential cover is reset to address the new hydrological and geomorphological conditions (Table 7.1).

Succession processes leading to indigenous forest in northern New Zealand

In northern New Zealand the most comprehensive evaluations of succession processes have been those leading to indigenous forest ecosystems. Key trends have been compiled as part of the process of developing tables for scoring progress towards present-potential cover. Figure 7.2 is the main text of Chapter 7 represents the primary succession trends for those areas where the *present-potential cover* is indigenous forest.

Mainland northern New Zealand

It takes many years for newly established pioneer vegetation on a secondary surface (one where soil has already formed) to develop into mature native forest, particularly a native conifer/mixed broadleaved forest. In Northland the native conifer component can be kauri and/or one or more of the podocarp species. Typically the coastal mixed broadleaved canopy component is dominated by large specimens of species such as taraire and puriri.

Throughout much of Northland excluding dunelands and wetlands, the primary early succession species is kanuka (*Kunzea ericoides*), sometimes with manuka. Initially kanuka forms dense scrub which develops into kanuka forest. Native canopy species establish under the kanuka forest and progressively overtop the kanuka as the vegetation evolves to become conifer/ mixed broadleaved forest. An analysis of New Zealand studies of kanuka and manuka growth and the associated succession patterns can provide guidance about succession processes and timing in different situations.

In Dunedin, Allen et al. (1992) found that kanuka established readily on bare ground and more slowly on grazed pasture. For 27-50 years dense kanuka stands of 1/sq m suppressed the growth of other tree species, but after 50 years kanuka stem density began to decrease, and after 70 years there were scattered podocarps with succession to mature broadleaved forest just beginning. They predicted that it would take several centuries for this vegetation to develop into mature podocarp/mixed broadleaved forest.

Further north, Esler & Astridge (1974) found that in the Waitakere Ranges kanuka and manuka reached 7m in 20 years, with kanuka over 100 years old exceeding 18 metres in height. They proposed two main succession routes. In the first, kauri established early and formed kauri rickers overtopping the kanuka; and growing to form a kauri/mixed broadleaved forest. In the second, podocarp seedlings established later (than the kauri seedlings) and developed into podocarp (especially rimu)/mixed broadleaved forest. On exposed steep coastal slopes stunted manuka dominated over a prolonged period and the future vegetation type was uncertain.

In Russell Forest in Northland, Lloyd (1960) evaluated the regeneration of kauri, rimu and tanekaha (*Phyllocladus trichomanoides*) under a kanuka canopy. He found few other species under young kanuka because of the intense competition and dense litter. While a few saplings of kauri, rimu and tanekaha established initially, for the next sixty years only tanekaha established. Once the kanuka stand reached 60 years of age kauri, rimu and tanekaha regenerated continuously. The kauri that established in the early years grew rapidly (reaching 23cm in diameter after 110 years). This contrasted with the suppression-induced slower growing kauri that established later. Several kauri trees of 109 years were 16.8m tall - slightly taller than older kanuka trees. Rimu and tanekaha were also present at heights at or close to the canopy.

The variability in the kauri age/diameter relationship reported by Ahmed & Ogden (1987) may be the result of different establishment timings as described by Lloyd (1960). Ahmed & Ogden (1987) found that individuals in the same 10cm diameter class varied in age by 300 years and growth rates were slower than those usually reported. They concluded that the normal attainable age for kauri was more than 600 years and individuals whose diameter was greater than 2 metres were probably more than 1000 years old.

The "cohort regeneration model" for kauri described by Ogden et al. (1987) was that dense kauri regeneration can follow large-scale disturbance. This is followed by self-thinning kauri ricker stands with rare seedling establishment thereby creating a local "regeneration gap". Once the forest becomes mature, canopy gaps resulting from windthrow, create opportunities for kauri recruitment.

In 100-200 year secondary kauri –tanekaha forest in Coromandel, the larger trees were beginning to develop mature crowns (Burns & Smale 1990). Trends included: tanekaha replacing second generation kanuka; and kauri replacing towai (*Weinmannia silvicola*), and probably tanekaha in future. Burns & Smale (1990) expected that over time kauri would generally become dominant and that canopy diversity would be enhanced by a few podocarps and hardwoods such as hinau (*Elaeocarpus dentatuts*) and kohekohe (*Dysoxylum spectabile*).

In Northland valley bottoms, present-potential cover is typically podocarp/mixed broadleaved forest. In the low altitude Wairongomai Valley in Kaimai Range, Bergin (1979) found that gorse (*Ulex europeaus*) and bracken dominated the youngest sites. Overtime a sequence of broadleaved species moved into the canopy. When the vegetation reached 300 years it was dominated by tawa with frequent podocarps.

Natural secondary totara sites are common in Northland. Totara can colonise open steep grazed slopes, often with manuka, kanuka and gorse (*Ulex europeaus*) (Bergin 2001). As totara increases in height the shorter stature species such as manuka and gorse are eventually suppressed although the longer lived kanuka can remain a significant component in the canopy for several decades. Totara-dominant stands of 50-70 years average 9-14 metres, while stands of 80-120 years average 16-20 metres (Bergin 2001). Totara in Northland can live to at least 600 years.

Islands and mainland exposed open coast

A paper by Atkinson (2004) summarises succession trends after fires observed during 50 years of research on northern offshore islands larger than 15 hectares. Succession was typically to a broadleaved canopy dominated by tairaire or tawa (*Beilschmedia tawa*) and kauri was rarely found. It is likely that Atkinson's observations also apply to succession trends on exposed mainland coastal sites where human disturbance has been periodic rather than ongoing. In both types of locations availability of seed and local site conditions largely determine which succession route is followed.

Atkinson (2004) found that after an offshore island fire one or more of five pioneer species with wind-blown seeds (kanuka, manuka, pohutukawa, flax and bracken) established. The most widespread island succession pathway was that initiated by the establishment of pohutukawa and kanuka mosaics. Once the more salt tolerant pohutukawa and/or kanuka established succession was dominated by a suite of five bird-dispersed species, particularly mapou (*Myrsine australis*), mahoe (*Melicytus ramniflorus*), kohekohe, karaka (*Corynocarpus laevigatus*) and puriri (*Vitex lucens*). On favourable sites kohekohe and karaka (*Corynocarpus laevigatus*) could establish under a pohutukawa or kanuka canopy within 50-100 years of the initiating fire. Puriri needed more light, but established readily in kanuka forest. Taraire and/or tawa were next to enter the canopy.

The development of pohutukawa successions was found to be influenced by the effects of wind-driven salt and the increased soil fertility generated by burrow nesting petrels. Burrow nesting seabirds were once common on the mainland (Hamil et al. 2003) and influenced succession process there as well.

Atkinson (2004) observed that pohutukawa could maintain a continuous canopy for at least 100 years and individual trees could live for 300 years or more. On favourable sites on Hen Island (near Whangarei), taraire or tawa could become dominant within 200 years of the initiating fire provided that they established within a pohutukawa forest soon after it formed a closed canopy.

Where kanuka formed the initial canopy, succession was often faster than under pohutukawa. On Little Barrier Island (outer Hauraki Gulf) much of the extensive kanuka forest on lower slopes was 100-125 years old. It was thinning rapidly. Replacement species were haekaro (*Pittosporum umbellatum*) with juvenile kohekohe and puriri. Where taraire and/or tawa established, especially in valley sites, Atkinson (2004) expected that either or both would dominate within 150 years of the initiating fire. On low fertility sites kauri was thought to be the likely replacement, although this would take much longer. In contrast to the northern mainland, conifers are rare on northern islands undergoing post-fire successions and where they do occur they are in uncommon habitats (Bellingham et al. 2010). High soil phosphorus levels resulting from inputs from past and present seabird colonies are expected to favour angiosperm dominance because New Zealand conifers are best adapted to infertile soils (Coomes et al. 2005).

Other common starting points for island succession were manuka scrub and bracken fernland. Manuka can overtop the bracken and then be overtopped by mapou. Mapou is short-lived and so the resulting forest is usually kohekohe or karaka forest with scattered pohutukawa (where the pohutukawa established at the same time as the manuka.). Atkinson (2004) found areas of manuka on poor soils with a low and tight canopy showing little evidence of any succession. Flax (*Phormium tenax*), like pohutukawa, is very resistant to salt and is common as a long term coastal cliff and shoreline fringe species.

Effects of naturalised species on forest succession

As Northland was the first area of New Zealand to be extensively settled by Europeans and it possesses a mild sub-tropical climate, it has many naturalised plant species. The rate of plant naturalisation in nearby Auckland is 4.12 new species per year (Esler 1988). Many of these naturalised species alter forest and other succession processes (e.g. (Williams et al. 2003)). They are especially common near human settlement (Esler 1988; Sullivan et al. 2005; Sullivan et al. 2009).

Naturalised plant pest (Craw 2000; Biosecurity New Zealand 2008) species (e.g. gorse (*Ulex europaeus*), wattles, privet, pampas, pines, tobacco weed (*Solanum mauritianum*) and hakea) or environmental weeds (Howell 2008) may establish with young kanuka and in some cases these naturalised species may dominate the vegetation. Successions that begin with naturalised gorse rather than kanuka show more differences in species composition in mature stands than expected and it is likely that they are leading to divergent outcomes (Sullivan et al. 2007). Williams & Karl (2002) found the different morphology and structure of gorse encouraged greater use by introduced species of bird and animal (compared to kanuka) and a greater chance of succession leading to vegetation dominated by naturalised woody species.

Pampas can quickly colonise disturbed sites, quickly forming very dense stands that prevent the establishment of other species. Eventual succession is typically to naturalised vines (Craw 2000) such as Japanese honeysuckle (*Lonicera japonica*), mothplant (*Araujia sericifera*) and blue morning glory (*Ipomoea indica*).

Wattles (e.g. *Acacia dealbata*) are common components of pioneer forest and scrub canopies in parts of the Bay of Islands. Eventually native forest species should grow above the wattles (Craw 2000). Tobacco weed is a common invader of disturbed forest, scrub and coastal margins where it can form pure stands that inhibit recruitment by native species and slow regeneration (Craw 2000). Tree privet (*Ligustrum lucidum*) and monkey apple (*Acmena smithii*) can both form dense carpets of seedlings under the existing vegetation canopy. Where there is any damage to the canopy the seedlings can grow to become the new permanent canopy. Both species can form pure associations (Craw 2000). Chinese privet (*Ligustrum sinense*) forms dense stands that can prevent the recruitment of native tree species.

Dense kikuyu grass (*Pennisetum clandestinum*) can delay the initial establishment of woody tree species for many years – thereby delaying the start of the succession process. Pest plants that form a dense ground cover under early succession species can distort or delay succession processes. For example dense Tradescantia (*Tradescantia fluminensis*) can prevent the establishment of native canopy species. As more species naturalise and existing naturalised species continue to spread, non-native species will play an increasing (not usually beneficial) role in ecological succession processes.

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Appendix 6: Summary of perception study trials

Trials used to refine methodology used to collect naturalness perception data

An initial trial using the photograph set incorporated into a Powerpoint presentation and a draft form was run by my Lincoln University supervisor using a group of undergraduate planning students. In this trial no background information was provided beforehand and the students chose to view each image for 10 seconds. There were some anomalous results from this trial which demonstrated the need to provide an adequate briefing before participants began scoring. Some refinements were made to the scoring/background information sheet. The first was to revise the layout of the section where participants recorded their scores to reduce the risk of scores being assigned to the wrong photograph. The second was some minor changes to the background information section.

On a subsequent visit to Waikato University I ran a second trial that tested several time options for viewing the photographs. Fifteen seconds was selected as a good compromise between giving people enough time to look at each photograph and preventing them from getting restless. In this trial all photographs were shown in quick succession first so that participants could view the full range of situations covered by the 40-photograph set before they viewed the photographs more slowly for scoring. A briefing was provided.

The protocols developed as part of, or as a consequence of, the Waikato University trial were used for subsequent participant scoring sessions. Minor additional protocols were added during the first public meeting. For example, the number of each photograph was called out as the photograph first appeared on screen. This was to assist those with problems viewing screen detail (and reduce the risk of scores being attributed to the wrong photograph).

Background/ contextual information provided by participants

Each participant received a one page form on which they scored the images in numbered boxes and provided a limited amount of background contextual information about themselves (Appendix 7). The background information collected was used to determine whether there were trends in participant scores and certain participant characteristics. The first type of background information requested that a box representing the most appropriate category be identified. Categorical information was directly collected for age group, gender, ethnicity, citizenship/residency, and familiarity with New Zealand mangroves. For the second type of background participants were asked to provide short written answers. These answers were subsequently sorted into categories that were determined after the written answers had been evaluated. Information collected using this format included tertiary qualification subject area(s), occupation/activities and experience with coastal management. The information received on coastal management experience was too inconsistent to categorise and so was not included in analyses.

The background information primarily addressed matters that have been shown to be potentially relevant in other studies (sections 8.2.1. and 8.2.2) or may be of relevance to coastal Northland. The question about citizenship/New Zealand residency was included because many properties in the Bay of Islands and some other eastern Northland coastal locations are owned by non-residents who visit primarily in the summer months. This was not a particularly relevant question in the context of the current study as the forums used to obtain natural character assessments did not generally include people who were not New Zealand residents.

The question about mangrove familiarity (in categories) was included because there has been considerable discussion about the causes and dynamics of indigenous mangrove spread in northern New Zealand locations (Mom 2005; Morrisey et al. 2007; Stokes et al. 2009b, a). Further south, in Tauranga and Whangamata Harbours, mangroves have already been removed from small areas (section 7.3.5) and there are proposals for other locations. The term “familiarity” was used as it was considered to be a relatively neutral term, although Kaplan and Herbert (1987) found that people do not necessarily prefer what they are familiar with and that interest and expertise may be more relevant. While the current study addressed participants’ assessments of naturalness (rather than preference) it was considered that it would be useful to identify any correlation between self-reported familiarity with mangroves and naturalness assessments, especially for those photographs where mangroves had been disturbed or removed.

Appendix 7: Natural character image assessment work sheet

Code: **0=no natural character; 100=maximum natural character**

Image Number	**Your natural character score (0-100) Terrestrial**	**Image Number**	**Your natural character score (0-100)Terrestrial**	**Image Number**	**Your natural character score (0-100) Marine**
1		**15**		**29**	
2		**16**		**30**	
3		**17**		**31**	
4		**18**		**32**	
5		**19**		**33**	
6		**20**		**34**	
7		**21**		**35**	
8		**22**		**36**	
9		**23**		**37**	
10		**24**		**38**	
11		**25**		**39**	
12		**26**		**40**	
13		**27**			
14		**28**			

Contextual information about you

1. Please tick the relevant boxes (one option for each question)

<table>
<tr><td>Age group</td><td>18-30</td><td>31-45</td><td>46-65</td><td>66+</td><td colspan="2"></td></tr>
<tr><td colspan="3">Level of familiarity with New Zealand mangrove coastlines</td><td>None</td><td>Limited</td><td>Moderate</td><td>High</td></tr>
<tr><td>Gender</td><td>Male</td><td>Female</td><td>NZ Born?</td><td>Yes</td><td colspan="2">No</td></tr>
<tr><td>Citizenship/ visitation</td><td>New Zealand citizen</td><td>New Zealand resident</td><td>Regular visitor to NZ</td><td>Occasional visitor to NZ</td><td colspan="2">First visit to NZ</td></tr>
<tr><td>Ethnicity</td><td>New Zealand European</td><td>New Zealand Maori</td><td>Polynesian or Melanesian</td><td>Other European</td><td>Asian</td><td>Other</td></tr>
</table>

2. Please write your answer in the right hand column

Tertiary qualification subject area(s)	
Occupations/ expertise	
Involvement in coastal or environmental management (paid or voluntary)	

Appendix 8: Participant consent form

Information for participants **Code:**

I am a PhD student at the International Global Change Institute (IGCI) at the University of Waikato. My research topic is "Evaluating the outcomes of the long-standing New Zealand policy goal to preserve the natural character of the coastal environment in eastern Northland"

Part of my research involves identifying how different groups of people perceive coastal natural character by using standard psychophysical methods. I will be asking you score what you perceive to be the amount of natural character in 40 carefully selected images. You will also be asked to provide some information about yourself to assist with data analysis.

I anticipate that your assessment should take about 15-20 minutes. It is likely that I will use the information you and many others provide in my PhD thesis as well as in any publications that arise as part of my studies.

Should you, at some point prior to 31 October 2009, decide to withdraw your participation from this project, it is possible to contact the researcher, and have the information you have given deleted from the data set. To do this, all you need is the coding number from the top of this page. After this time, it will be understood that you have consented to participate in the project, and consent to publication of the results with the understanding that anonymity will be preserved

This project has been reviewed and approved by the University of Waikato's Faculty of Science Ethics Committee. Should you have any concerns about the research or the conduct of the researcher please contacts either my chief supervisor or I (contact details appear below)

My contact details are as follows
Victoria Froude [redacted] vfroude@slingshot.co.nz ;

Chief supervisor, Professor Janet Bornman– daytime phone (07) 856 2889; email: jbornman@waikato.ac.nz postal address: International Global Change Institute, University of Waikato, Private Bag 3105, Hamilton
Supervisor: Dr Hamish Rennie; Phone: (64) (03) 325 3838 ext 8002; hamish.rennie@lincoln.ac.nz

I agree to participate in this natural character image assessment project and consent to the use of the information I provide, including publication of the results, with the understanding that anonymity will be preserved.

Signature:_________________________________

Date:_____________________

Appendix 9: Photographs assessed by participants


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GILMORE BROWN
BUSINESS ADVISERS
CHARTERED ACCOUNTANTS
TO LEASE


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Refuse Barge


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Berth 1
SLOW
NO WAKE
ZONE


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40

Appendix 10: Participant and calculated scores for natural character for the 40 photographs

Image no	Image description	ratio %sky/100	ratio %water/100	ratio %NS/100	ratio %NA vege/100	ratio %BA/100	ratio %building/100	ratio % structure/100	ratio %pave/100	ratio total
T1	native forest and saltmarsh, Man of War Creek, Waikare Inlet	0.06	0	0	0.94					1
T2	cranes, containers and paved, Ports of Auckland	0.1					0.08	0.4	0.42	1
T3	house in grass above pohutukawa scrub on cliff, gravel beach, Coast north of Cape Wiwiki	0.06	0.08	0.19	0.48	0.16	0.02	0.01		1
T4	house, seawall, pasture, Sandy Bay, Whangaruru	0.1	0	0.02	0.04	0.39	0.27	0.18		1
T5	house below pohutukawa, low mangroves and back dune grasses, Waipu Cove	0.02	0.03	0	0.84	0.03	0.07	0.01		1
T6	house & retaining wall on mangrove shore, kanuka scrub on hill, Wakare Inlet south	0	0	0.09	0.75	0	0.12	0.04		1
T7	bach in mixed vegetation on water's edge, Te Uenga Bay, Parekura	0.07	0.07	0.03	0.73	0.07	0.02	0.01		1
T8	house on sandy beach, mixed broadleaved scrub, pine plantation, Taupo Bay	0	0	0.08	0.25	0.53	0.09	0.05		1
T9	beachfront settlement, native vegetation on hills, Tapeka	0.07	0	0.02	0.43	0.25	0.2		0.03	1
T10	houses, grass, shingle beach, Tapeka	0.06	0	0.03	0.01	0.74	0.15	0.01		1
T11	houses in kanuka forest & scrub, beach; Paihia south	0.02	0	0.08	0.73	0.06	0.09	0.02		1
T12	Auckland CBD and Viaduct Basin	0.26	0	0	0	0.01	0.7	0.03		1
T13	native forest and water Parekura Bay	0.07	0.08		0.85					1
T14	campground and vegetated hills, Bland Bay	0.09	0	0.02	0.25	0.59	0.04	0.01		1
T15	houses on vegetated hill crest, water edge embankment south Opua	0.09	0.1	0	0.67	0.05	0.08	0.01		1
T16	surf club building, dunes with native & introduced species, paved	0.04	0	0.1	0.59	0.05	0.15	0.02	0.05	1
T17	houses behind mature pohutukawas, rock seawall, Rawhiti	0.04	0.03	0.1	0.6	0.07	0.06	0.1		1
T18	red house on top of vegetated coastal hill, Rawhiti	0.06	0.01	0.09	0.8	0.01	0.02	0.01		1
T19	apartments on top vegetated cliff, Parnell	0.05	0.01	0.03	0.58	0.02	0.31			1
T20	hill dominated by native vegetation, Paihia Beach Resort hotel, paved	0.12	0	0	0.3	0.07	0.44		0.07	1
T21	shore oyster processing facility, few mangroves, Orongo Bay	0	0.03	0.03	0.15	0.1	0.31	0.3	0.08	1
T22	houses on cliff, native dominant vegetation, walkway north of Opua	0.08	0.02	0.17	0.62	0.04	0.07			1
T23	native vegetation & houses on hill, large sheds, rock wall & oc mangrove, Opua	0.04	0.09	0.08	0.29	0.05	0.3	0.15		1
T24	apartment block, houses, kanuka scrub, Haumi River margin with young mangroves, Te Haumi	0.03	0.04	0.1	0.27	0.18	0.29	0.04	0.05	1
T25	mangrovesHatea River, palms, buildings Whangarei CBD	0.15	0.01	0	0.24	0.1	0.5			1
T26	sand, grass, several houses, hills with native forest, Bland Bay	0.04	0	0.22	0.11	0.51	0.11	0.01		1
T27	barn, pasture and pine plantation at beach, Bland Bay	0.06	0	0.1	0	0.81	0.02	0.01		1
T28	cottage on dunes, grass behind; Bland Bay	0.11	0	0	0.6	0.25	0.04			1
M29	wharf, shed, cranes Princes Wharf Auckland	0.05	0.28	0	0	0	0.45	0.22		1
M30	Forested catchment (mostly native), estuarine flats, Punaruku E	0.06	0.16	0.45	0.32	0.01				1
M31	Oyster processing shed, hills behind, Waikare	0.08	0.58	0	0.06	0	0.28			1
M32	oyster farm detail with boats		0.05	0.25	0.4	0	0.02	0.28		1
M33	mangroves, jetty and ramp, Orongo Bay	0.1	0.01	0.2	0.39	0	0	0.3		1
M34	floating house and boats, Orakei Marina	0.12	0.5	0	0.02	0	0.04	0.32		1
M35	spinifex on dune looking out to Hen & Chickens Is, Waipu	0.04	0.32	0.23	0.41					1
M36	rubbish barge outer BOI	0.37	0.4	0	0.02	0.01	0	0.2		1
M37	oyster farm detail, Orongo Bay	0	0.35	0.25	0.13			0.27		1
M38	Opua Cruising Club building and large boats in marina	0.19	0.45	0	0	0	0.14	0.22		1
M39	training walls leading to a marina, Orakei	0	0.66	0	0.15	0	0	0.19		1
M40	oyster shed and mangroves, Waikare	0	0.25	0	0.54	0	0.17	0.04		1

Image no	minus sky ratio total (1-sky ratio)	adjust water ratio	adjust NS ratio	adjust NA ratio	adjust BA ratio	adjust bldg ratio	adjust structure ratio	adjust pave ratio	adjust ratio total	water now vs pot	NS now vs pot	NA native ratio	NA now vs pot	BA native ratio
T1	0.94	0.00	0.00	1.00	0.00	0.00	0.00	0	1			1	0.85	
T2	0.9	0.00	0.00	0.00	0.00	0.09	0.44	0.47	1					
T3	0.94	0.09	0.20	0.51	0.17	0.02	0.01	0	1	1	1	0.8	0.5	0.01
T4	0.9	0.00	0.02	0.04	0.43	0.30	0.20	0	1		0.75	0.9	0.3	0.15
T5	0.98	0.03	0.00	0.86	0.03	0.07	0.01	0	1	0.8		0.8	0.6	0.1
T6	1	0.00	0.09	0.75	0.00	0.12	0.04	0	1	0.8	0.4	0.85	0.4	
T7	0.93	0.08	0.03	0.78	0.08	0.02	0.01	0	1	1	0.9	0.9	0.6	0.25
T8	1	0.00	0.08	0.25	0.53	0.09	0.05	0	1		0.7	0.85	0.4	0.1
T9	0.93	0.00	0.02	0.46	0.27	0.22	0.00	0.03	1		0.8	0.95	0.6	0.1
T10	0.94	0.00	0.03	0.01	0.79	0.16	0.01	0	1		0.8	0.9	0.5	0.04
T11	0.98	0.00	0.08	0.74	0.06	0.09	0.02	0	1		0.9	0.8	0.55	0.1
T12	0.74	0.00	0.00	0.00	0.01	0.95	0.04	0	1					0.5
T13	0.93	0.09	0.00	0.91	0.00	0.00	0.00	0	1	1		1	0.85	
T14	0.91	0.00	0.02	0.27	0.65	0.04	0.01	0	1		0.9	0.98	0.7	0.15
T15	0.91	0.11	0.00	0.74	0.05	0.09	0.01	0	1	0.9		0.75	0.52	0.5
T16	0.96	0.00	0.10	0.61	0.05	0.16	0.02	0.05	1		0.4	0.53	0.5	0.1
T17	0.96	0.03	0.10	0.63	0.07	0.06	0.10	0	1	1	0.9	0.95	0.75	0.4
T18	0.94	0.01	0.10	0.85	0.01	0.02	0.01	0	1		0.85	0.95	0.58	0.01
T19	0.95	0.01	0.03	0.61	0.02	0.33	0.00	0	1	0.8	0.8	0.85	0.6	0.01
T20	0.88	0.00	0.00	0.34	0.08	0.50	0.00	0.08	1			0.95	0.65	0.2
T21	1	0.03	0.03	0.15	0.10	0.31	0.30	0.08	1	0.8	0.8	0.8	0.6	0.01
T22	0.92	0.02	0.18	0.67	0.04	0.08	0.00	0	1	0.8	0.55	0.8	0.4	0.05
T23	0.96	0.09	0.08	0.30	0.05	0.31	0.16	0	1	0.7	0.45	0.75	0.45	0.7
T24	0.97	0.04	0.10	0.28	0.19	0.30	0.04	0.05	1	0.8	0.7	0.95	0.35	0.1
T25	0.85	0.01	0.00	0.28	0.12	0.59	0.00	0	1	0.8		0.95	0.68	0.01
T26	0.96	0.00	0.23	0.11	0.53	0.11	0.01	0	1		0.8	0.9	0.6	0.08
T27	0.94	0.00	0.11	0.00	0.86	0.02	0.01	0	1		0.85			0.01
T28	0.89	0.00	0.00	0.67	0.28	0.04	0.00	0	1			0.85	0.65	0.25
M29	0.95	0.29	0.00	0.00	0.00	0.47	0.23	0	1	0.8				
M30	0.94	0.17	0.48	0.34	0.01	0.00	0.00	0	1	1	0.95	0.95	0.7	0.05
M31	0.92	0.63	0.00	0.07	0.00	0.30	0.00	0	1	0.7		0.9	0.5	
M32	1	0.05	0.25	0.40	0.00	0.02	0.28	0	1	0.8	0.7	0.8	0.4	
M33	0.9	0.01	0.22	0.43	0.00	0.00	0.33	0	1	0.8	0.6	1	0.7	
M34	0.88	0.57	0.00	0.02	0.00	0.05	0.36	0	1	0.9		0.35	0.2	
M35	0.96	0.33	0.24	0.43	0.00	0.00	0.00	0	1	1	0.95	0.99	0.85	
M36	0.63	0.63	0.00	0.03	0.02	0.00	0.32	0	1	1		0.35	0.25	0.1
M37	1	0.35	0.25	0.13	0.00	0.00	0.27	0	1	0.8		0.9	0.35	
M38	0.81	0.56	0.00	0.00	0.00	0.17	0.27	0	1	0.8	0.7			
M39	1	0.66	0.00	0.15	0.00	0.00	0.19	0	1	0.85		0.95	0.6	
M40	1	0.25	0.00	0.54	0.00	0.17	0.04	0	1	0.7		0.8	0.65	

Image no	BA now vs pot	Build colour	Build reflect	Struct colour	Struct reflect	HG1 mag	HG 1% area	HG 2 mag	HG 2 % area	NS score	NA score	BA score	water score
T1						0				0.00	0.85	0.00	0.00
T2		1	1	1	1	1	0.5	0.9	0.5	0.00	0.00	0.00	0.00
T3	0.1	0.8	0.9	0.8	0.9	0.2	0.03			0.20	0.26	0.02	0.09
T4	0.1	1	1	1	1	0.3	0.1			0.02	0.01	0.04	0.00
T5	0.1	1	1	0.8	0.8	0.1	0.05			0.00	0.51	0.00	0.02
T6		1	1	1	1	0.3	0.05			0.04	0.30	0.00	0.00
T7	0.15	1	1	1	1	0.1	0.01			0.03	0.47	0.01	0.08
T8	0.18	1	1	1	1	0.3	0.05			0.06	0.10	0.10	0.00
T9	0.1	1	1	1	1	0.1	0.2			0.02	0.28	0.03	0.00
T10	0.1	1	1	1	1	0.1	0.1			0.03	0.01	0.08	0.00
T11	0.15	1	1	0.9	0.9	0.2	0.05			0.07	0.41	0.01	0.00
T12	0.1	1	1	1	1	1	0.25			0.00	0.00	0.00	0.00
T13						0				0.00	0.78	0.00	0.09
T14	0.1	1	1	1	1					0.02	0.19	0.06	0.00
T15	0.1	1	1	1	1					0.00	0.38	0.01	0.10
T16	0.15	1	1	0.8	0.8	0.5	0.2			0.04	0.31	0.01	0.00
T17	0.2	0.8	0.8	0.8	0.8	0.3	0.1			0.09	0.47	0.01	0.03
T18	0.1	0.9	0.9	0.8	0.9	0				0.08	0.49	0.00	0.00
T19	0.1	1	1							0.03	0.37	0.00	0.01
T20	0.2	1	1							0.00	0.22	0.02	0.00
T21	0.1	1	1	1	1	0.1	0.1			0.02	0.09	0.01	0.02
T22	0.1	1	1							0.10	0.27	0.00	0.02
T23	0.1	0.9	0.8	1	1					0.04	0.14	0.01	0.07
T24	0.1	1	1	1	1	0.1	0.1			0.07	0.10	0.02	0.03
T25	0.1	1	1	1	1	0.1	0.05			0.00	0.19	0.01	0.01
T26	0.1	0.9	0.9	0.8	0.8					0.18	0.07	0.05	0.00
T27	0.1	0.8	0.8	0.8	0.8					0.09	0.00	0.09	0.00
T28	0.15	0.8	0.8							0.00	0.44	0.04	0.00
M29		1	1	1	1					0.00	0.00	0.00	0.24
M30	0.2					0				0.45	0.24	0.00	0.17
M31				0.9	0.9					0.00	0.03	0.00	0.44
M32		1	1	1	1	0.1	0.25			0.18	0.16	0.00	0.04
M33				0.8	0.8					0.13	0.30	0.00	0.01
M34		1	1	1	1					0.00	0.00	0.00	0.51
M35						0				0.23	0.36	0.00	0.33
M36	0.1			0.8	0.9	0				0.00	0.01	0.00	0.63
M37				0.9	0.9	0.1	0.2			0.00	0.05	0.00	0.28
M38		1	1	1	1	0.3	0.1			0.00	0.00	0.00	0.44
M39				0.9	0.9	0.5	0.15			0.00	0.09	0.00	0.56
M40		0.9	0.9	0.9	0.9					0.00	0.35	0.00	0.18

Image no	Ecological naturalness index	HG impact	Hydrological geomorphological naturalness index	BSIS	Freedom from buildings & structures index FBSI	Public score trimmed mean	Natural character indexENI*HGNI* FBSI	Adjusted NCI *100
T1	0.85	0.00	1.00	0.00	1.00	91.49	0.85	85
T2	0.00	0.95	0.05	0.87	0.13	0.14	0.00	0
T3	0.56	0.01	0.99	0.02	0.98	58.75	0.54	54.34
T4	0.07	0.03	0.97	0.50	0.50	23.14	0.04	3.56
T5	0.54	0.01	1.00	0.08	0.92	53.36	0.50	49.71
T6	0.34	0.02	0.99	0.16	0.84	56.55	0.28	27.80
T7	0.59	0.00	1.00	0.03	0.97	73.47	0.57	56.71
T8	0.25	0.02	0.99	0.14	0.86	39.36	0.21	21.30
T9	0.32	0.02	0.98	0.24	0.76	33.30	0.24	24.00
T10	0.11	0.01	0.99	0.17	0.83	16.30	0.09	9.00
T11	0.49	0.01	0.99	0.11	0.89	44.05	0.44	43.57
T12	0.00	0.25	0.75	0.99	0.01	0.92	0.00	0.00
T13	0.86	0.00	1.00	0.00	1.00	95.57	0.86	86.29
T14	0.28	0.00	1.00	0.05	0.95	51.72	0.26	26.17
T15	0.49	0.00	1.00	0.10	0.90	54.27	0.44	43.91
T16	0.36	0.10	0.90	0.21	0.79	35.70	0.25	25.46
T17	0.61	0.03	0.97	0.11	0.89	63.65	0.53	52.71
T18	0.58	0.00	1.00	0.02	0.98	65.48	0.56	56.17
T19	0.40	0.00	1.00	0.33	0.67	40.12	0.27	27.09
T20	0.24	0.00	1.00	0.56	0.44	25.03	0.11	10.51
T21	0.15	0.01	0.99	0.67	0.33	23.26	0.05	4.87
T22	0.39	0.00	1.00	0.08	0.92	44.32	0.36	36.30
T23	0.24	0.00	1.00	0.38	0.62	19.58	0.15	15.11
T24	0.22	0.01	0.99	0.38	0.62	22.22	0.14	13.63
T25	0.21	0.01	1.00	0.59	0.41	15.79	0.09	8.73
T26	0.31	0.00	1.00	0.10	0.90	36.57	0.27	27.48
T27	0.18	0.00	1.00	0.02	0.98	32.67	0.17	17.30
T28	0.48	0.00	1.00	0.03	0.97	42.98	0.47	46.65
M29	0.24	0.00	1.00	0.71	0.29	5.46	0.07	6.95
M30	0.87	0.00	1.00	0.00	1.00	93.10	0.87	86.54
M31	0.47	0.00	1.00	0.00	1.00	31.80	0.47	47.39
M32	0.38	0.03	0.98	0.30	0.70	27.77	0.26	25.59
M33	0.45	0.00	1.00	0.21	0.79	47.81	0.35	35.05
M34	0.52	0.00	1.00	0.41	0.59	8.14	0.30	30.49
M35	0.92	0.00	1.00	0.00	1.00	95.26	0.92	92.40
M36	0.64	0.00	1.00	0.23	0.77	32.37	0.50	49.71
M37	0.33	0.02	0.98	0.22	0.78	30.78	0.25	24.92
M38	0.44	0.03	0.97	0.44	0.56	12.44	0.24	23.95
M39	0.65	0.08	0.93	0.15	0.85	24.52	0.51	50.95
M40	0.53	0.00	1.00	0.17	0.83	44.14	0.44	43.65