Mangroves and seagrass: indicators of estuarine health?

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

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TE MĀTAURANGA PŪTAIAO ME TE PŪKAHA

Introduction

- Mangrove & seagrass are flowering plants adapted to saline conditions & varying degrees of submergence
- Sensitive to a range of environmental conditions
  - May be indicator species for estuarine health
- However, their interaction with marine environment may not be well understood … so we'll start by defining NZ estuary types

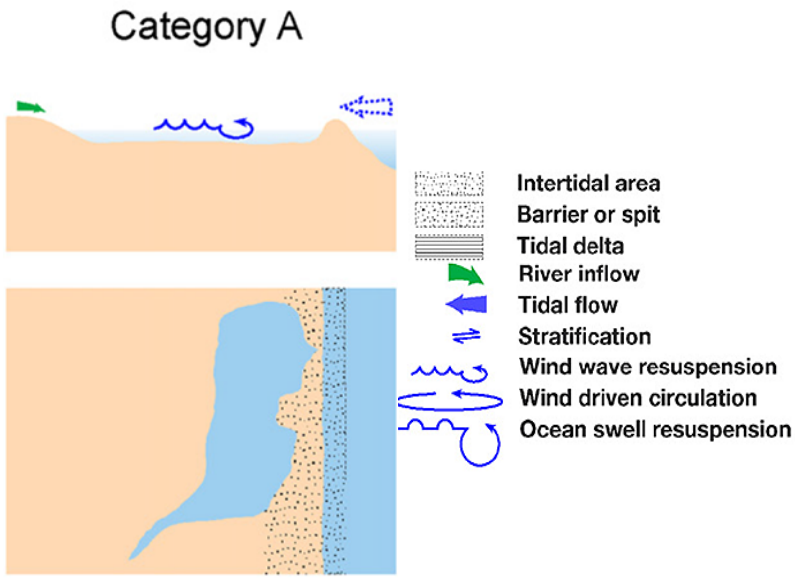
http://www.stuff.co.nz/auckland/local-news/manukau-courier/8028813/Taming-the-mangrove

https://www.niwa.co.nz/coasts-and-oceans/research-projects/restoration-of-seagrass-beds-in-whangarei-harbour

Estuary types – Coastal lakes

Lake Ellesmere

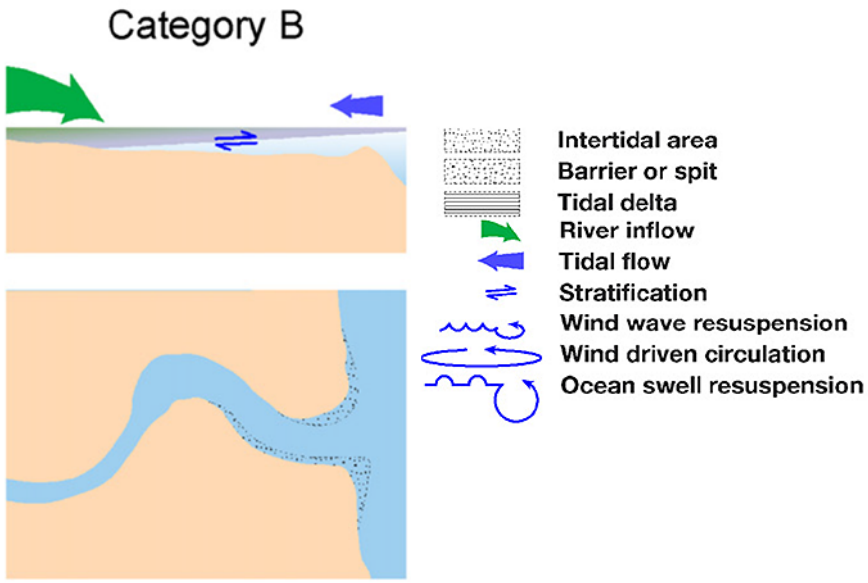
- Category A – Coastal lakes
  - Very shallow basins (several metres depth)
  - Often elongated & parallel to coast
  - Entrance is closed most of time
    - Little tidal influence
    - Poor flushing
    - Fine sediment accumulates
  - Include most contaminated fluvial/marine sites in NZ
    - Lake Ellesmere, Canterbury



Estuary types – River mouths

- Category B – Tidal river mouths
  - Elongated basins of simple shape
  - 1-10 m deep
- Category C – Tidal river lagoons (*Hapua*)
  - Mouth of main river channel connects to shallow lagoons
- River channel dominated by freshwater discharge
  - Well flushed
- Lagoons dominated by shallow intertidal areas
  - Limited mixing
  - Poorly flushed

Piako & Waihou Rivers, Waikato



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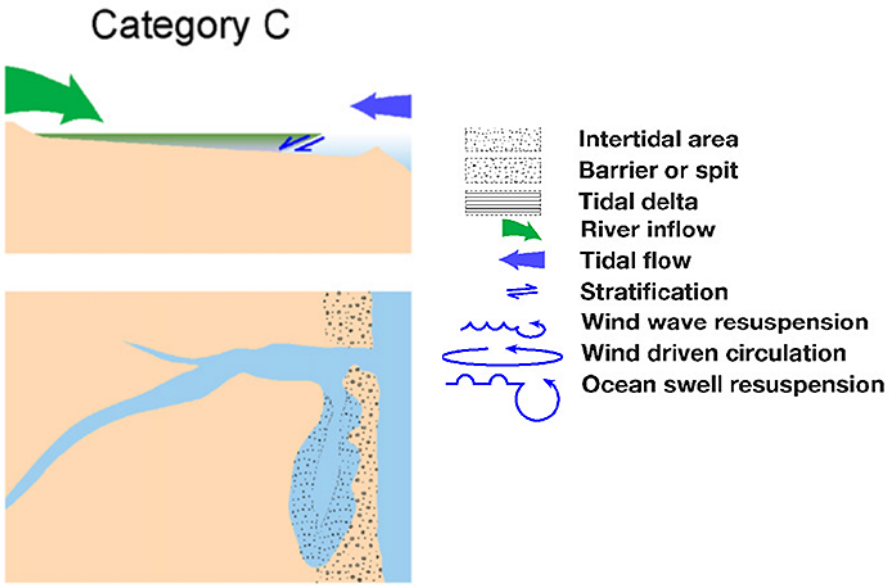
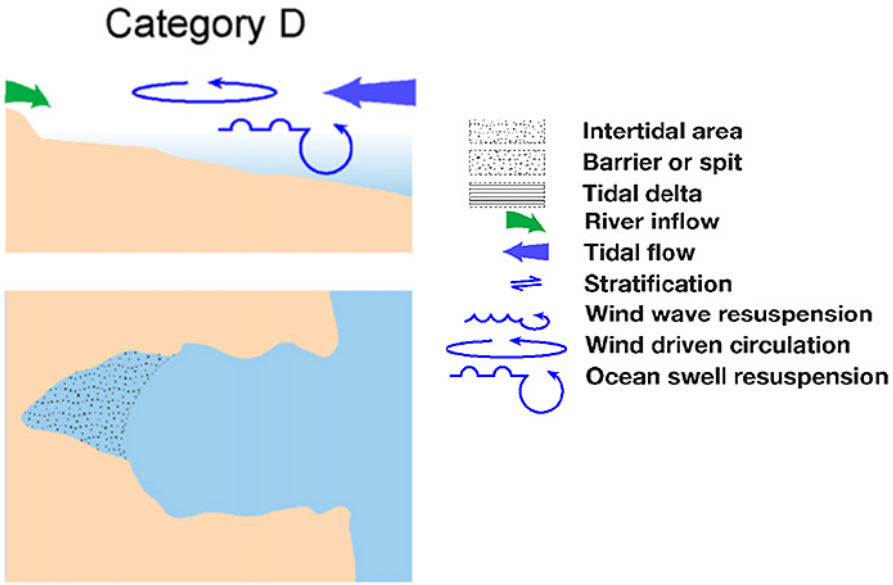
Waimakariri River, Canterbury



Estuary types – Coastal embayments

- Category D – Coastal embayments
  - Shallow, circular or slightly elongated basins with simple shorelines
  - Wide entrances open to ocean
  - Little fluvial input
  - Restricted intertidal areas
  - Predominantly sandy sediment

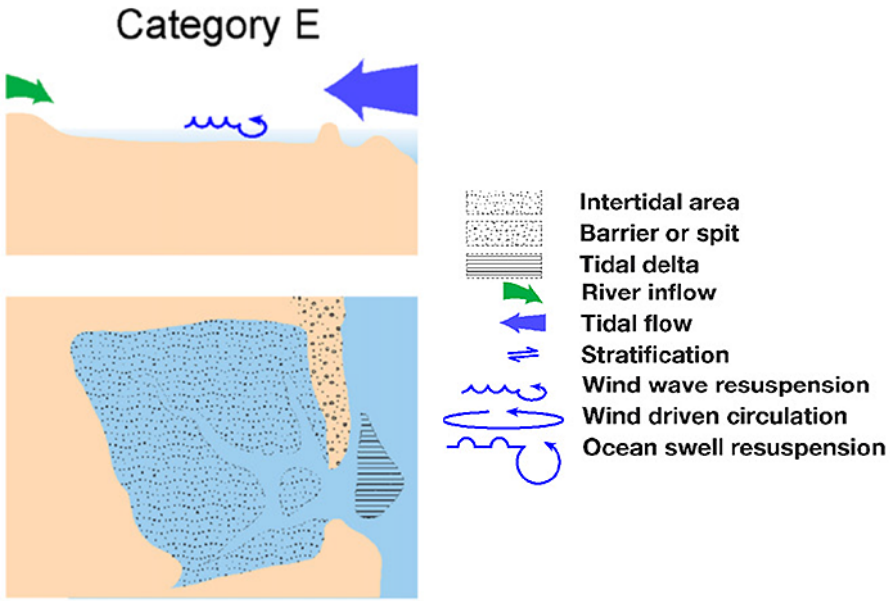


Okains Bay, Canterbury

Estuary types – Coastal lagoons

Houhora Harbour, Northland

- Category E – Tidal lagoons
  - Shallow, circular to slightly elongated basins with simple shorelines
  - Extensive intertidal area
  - Barrier enclosed coastal embayment
- Category F – Barrier enclosed lagoon
  - Similar to E, but complex shorelines & numerous arms leading off a main basin (*Ria*)
- Main basin is tidally dominated, well-mixed & flushed
- Arms poorly mixed & flushed



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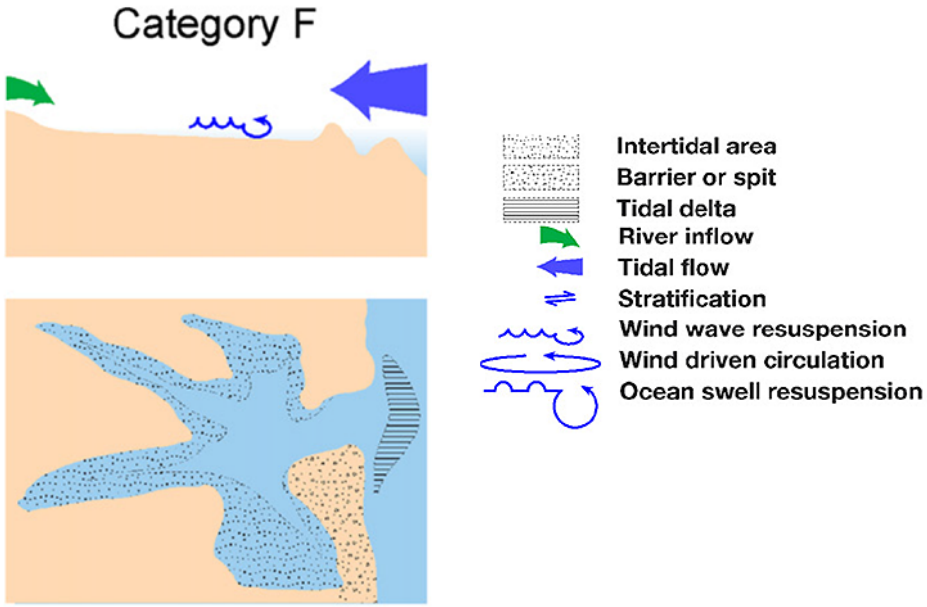
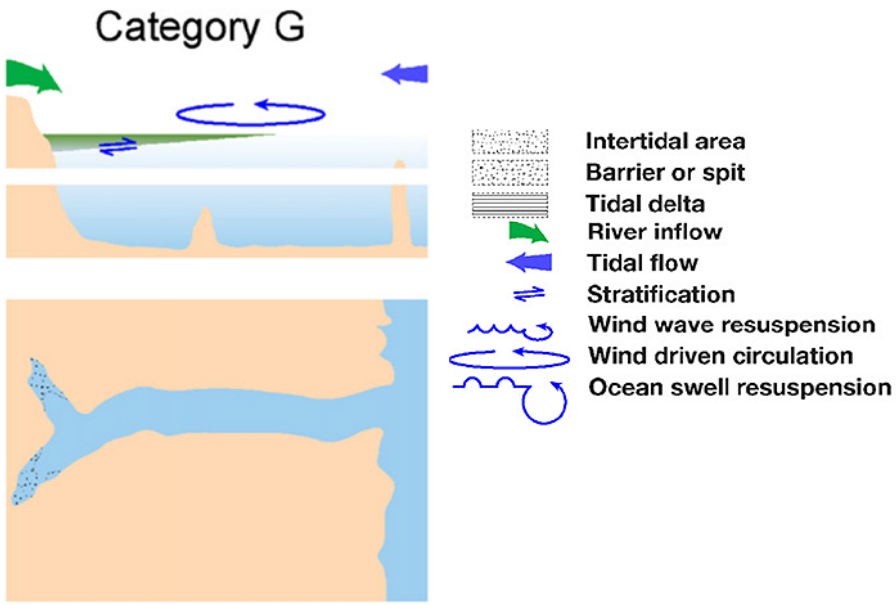
Whaingaroa Harbour, Waikato



Estuary types – Drowned valleys

- Category G – Fjords
  - narrow, elongated basins that are largely subtidal
  - Very deep (up to 100s of metres)
- Category H – Sounds & rias
  - Narrow, elongated basins that are largely subtidal
  - Deep (10s of metres)
- Moderate to strong stratification
- Poorly flushed
  - Tend to accumulate fine sediment

Bligh Sound, Fiordland



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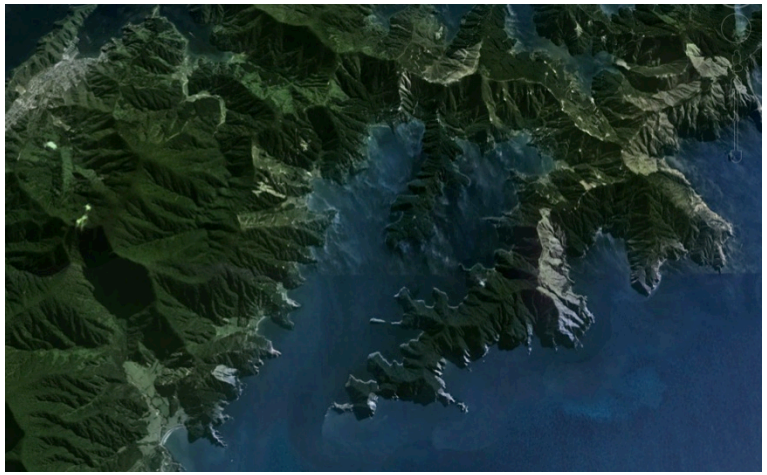
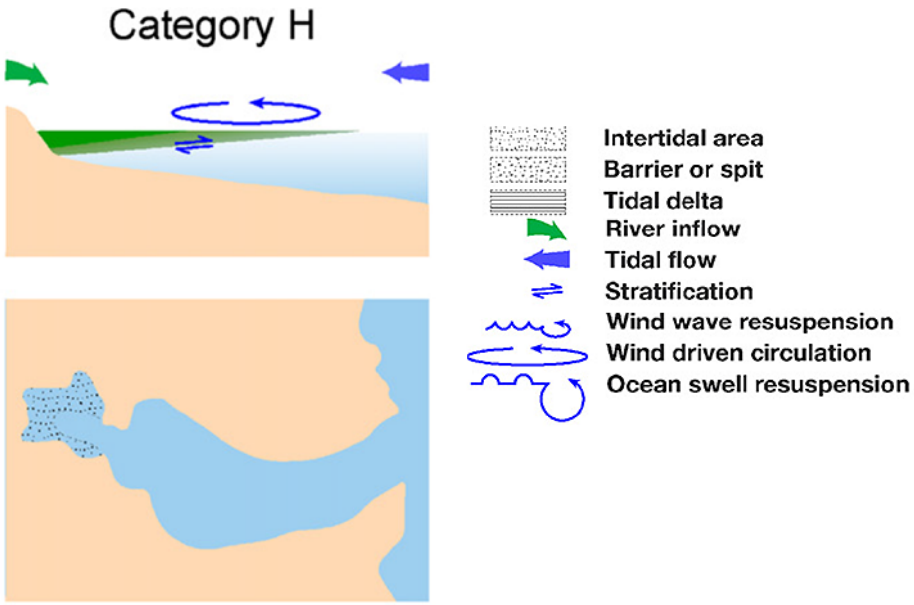
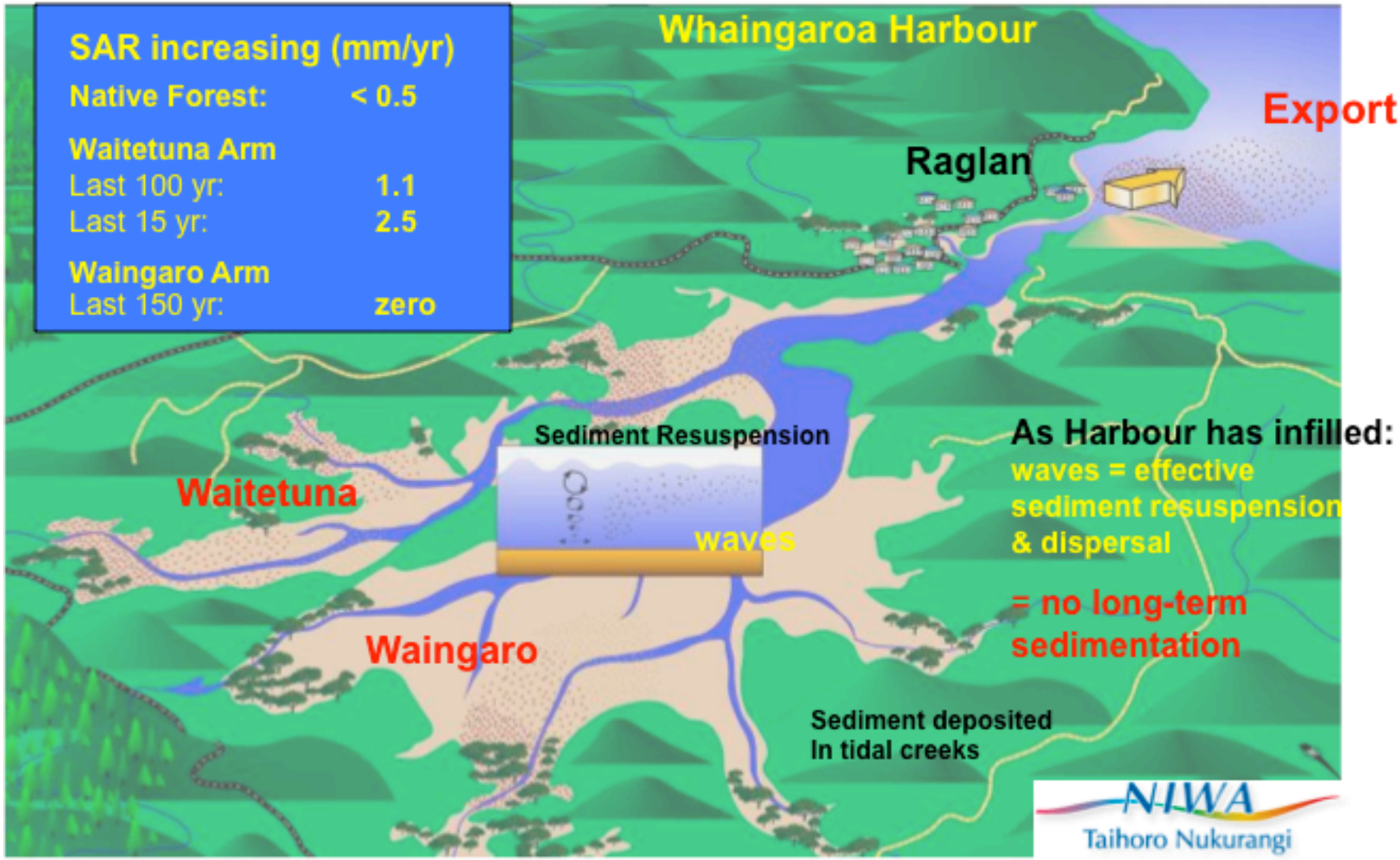


Port Underwood, Marlborough



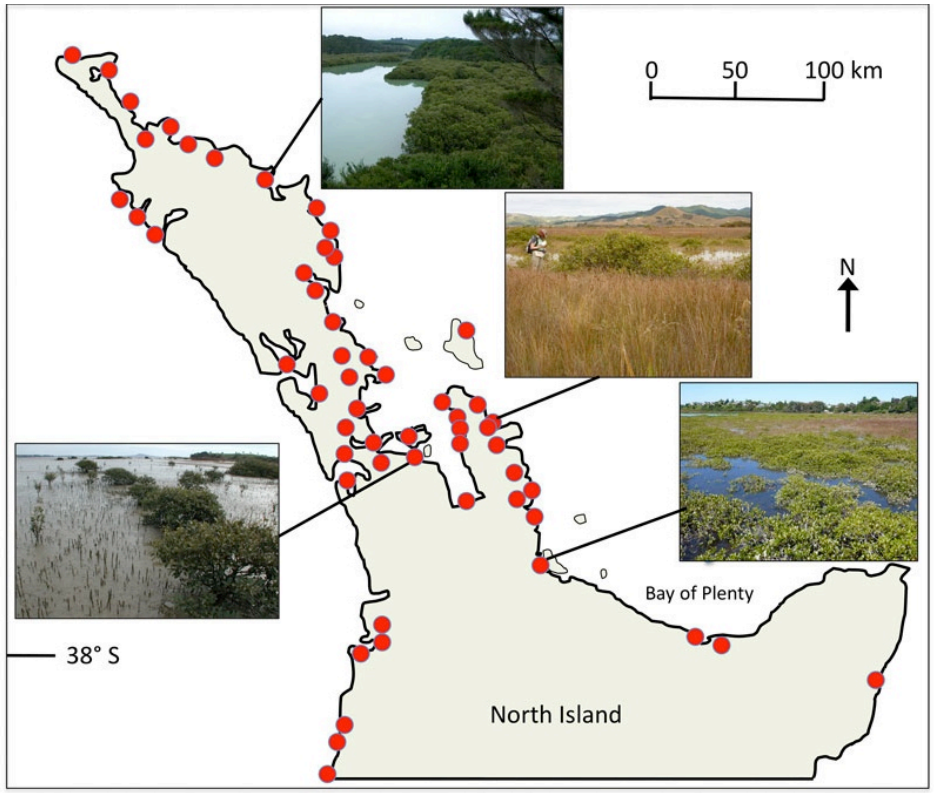
Raglan sedimentation



Wide range of conditions within single type of estuary

Mangrove

- Occur around upper North Island
  - Pollen data indicate range extended further south in recent past
- Expanded seawards since 1940s
  - Believed to be declining in 1970s due to reclamation & grazing
  - Some evidence that some populations are starting to decline
  - Debate about removal of mangroves to “restore estuarine environments”

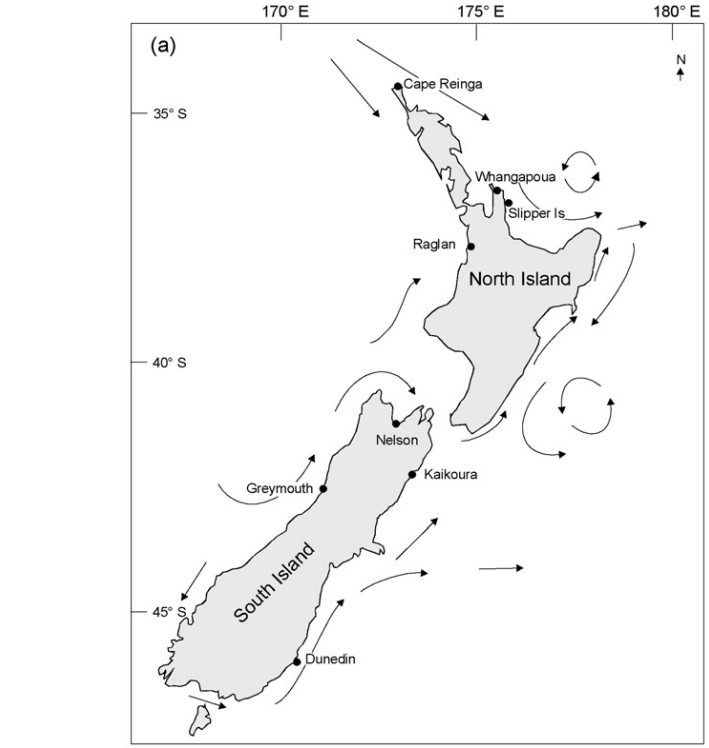


http://soundwaves.usgs.gov/2010/08/fieldwork4.html

http://www.stuff.co.nz/technology/80135951/hovercraft-mows-mangroves-in-tauranga

Seagrass

- Appearance (mostly size) varies around coast
- Debate about extent of genetic differences between & within “estuaries”
- Suggested different populations for North & South Islands



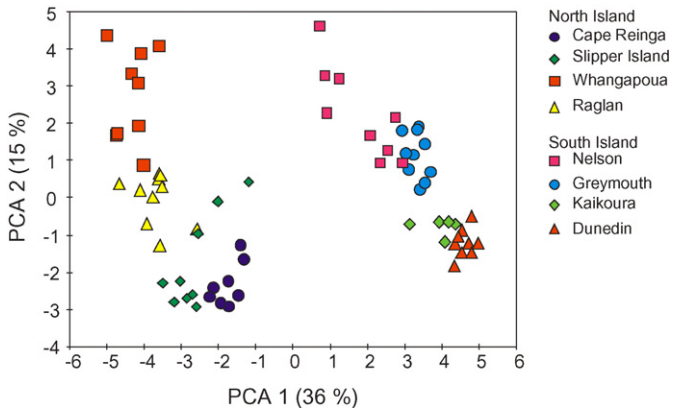


Fig. 4. Principle components analysis of genetic distances among individuals of *Zostera muelleri* from all study sites sampled across New Zealand. Localities as in Fig. 1.

Jones *et al* (2008). Genetic variability of New Zealand seagrass (Zostera muelleri) assessed at multiple spatial scales. Aquatic Botany, 88(1), 39–46. http://doi.org/10.1016/j.aquabot.2007.08.017

Seagrass

- Widely distributed around NZ coast
  - Not restricted to estuaries
  - No systematic survey of seagrass distribution &abundance throughout NZ has been undertaken
- Most literature (research) focussed on areas where seagrass is (or was) in decline
- Assumed that all NZ seagrass populations are threatened & in decline overall

Morrison *et al*, 2014. Seagrass Meadows as Biodiversity and Productivity Hotspots. New Zealand Aquatic Environment and Biodiversity Report No 137. MPI, Wellington

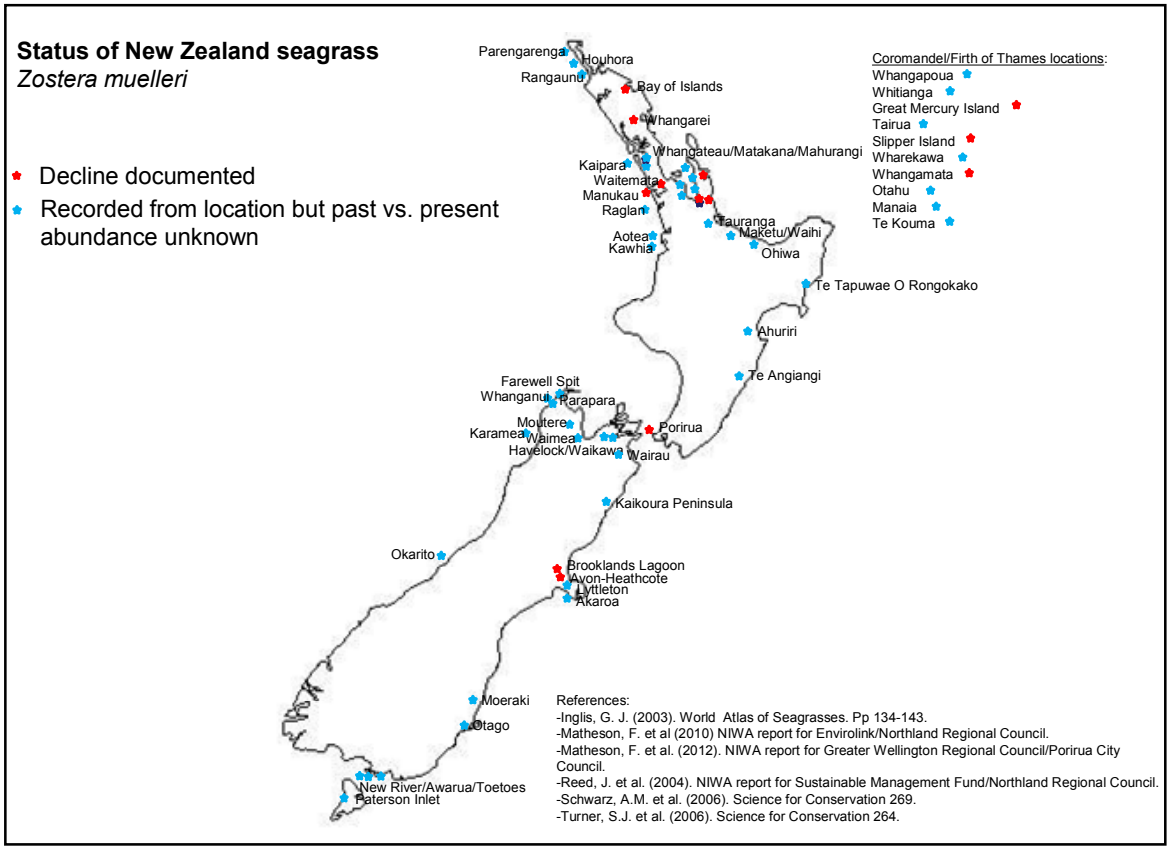
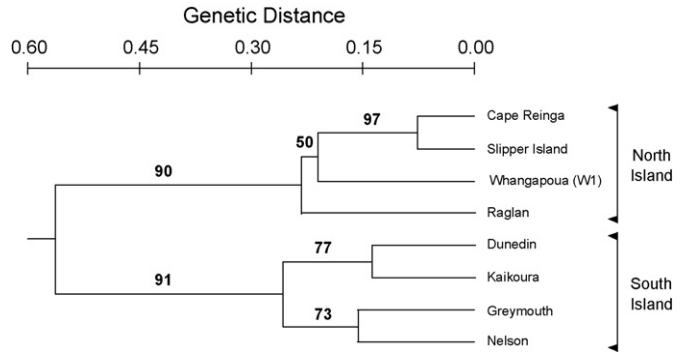


Figure 46: Known status of seagrass in New Zealand. Blue stars indicate documented locations, but the current status relative to its historical abundance is unknown for many of these sites. Red stars indicate documented cases of seagrass decline, with virtually all losses associated with human activities and development of these areas. The Department of Conservation has recently reclassified *Zostera muelleri*'s threatened species status, from stable to declining (Source: Matheson et al. 2011, Matheson & Wadhwa 2012).

Seagrass

- Sampling different locations gives a different result



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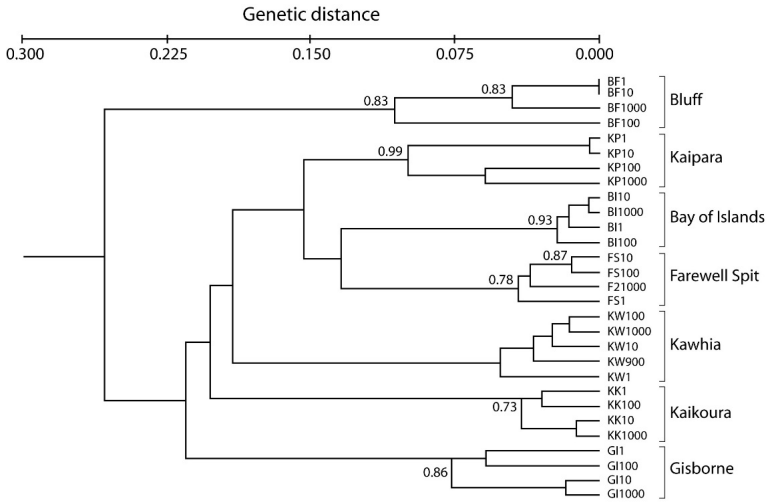


Morrison *et al*, 2014. Seagrass Meadows as Biodiversity and Productivity Hotspots. New Zealand Aquatic Environment and Biodiversity Report No 137. MPI, Wellington

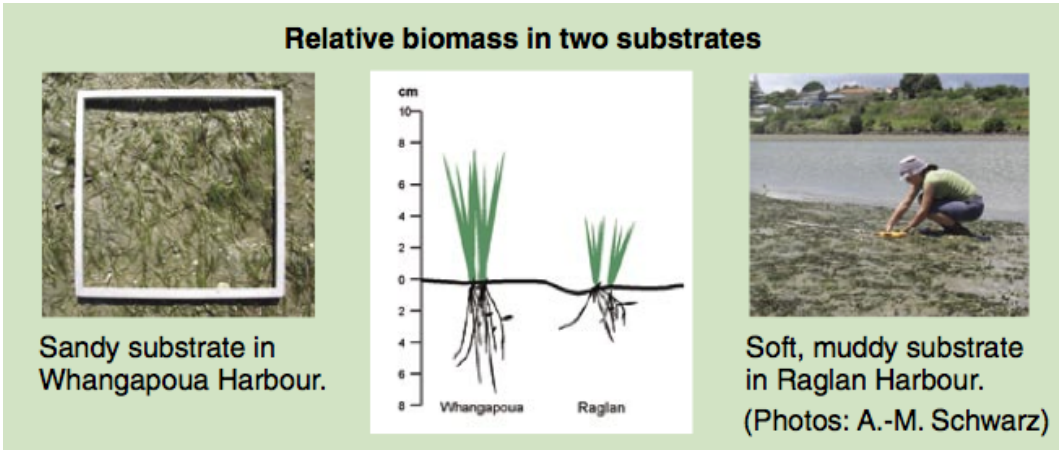
Simplified overview

	Mangrove	Seagrass
Sedimentation	Expansion	
Turbidity		Decline
Faunal biodiversity	Low	High
Faunal abundance	Low	High
NZ status	Expanding	Declining
Estuarine health indicated by presence	Poor?	Good?

Sediment texture

- Linked to growth
- Both can survive on a wide range of substrates
  - Mangrove grow best on fine sand
  - Seagrass best on a mixture of medium sand, fine sand & mud

Schwarz *et al* (2004). The role of sediment in keeping seagrass beds healthy. Water & Atmosphere 12(4):18-19



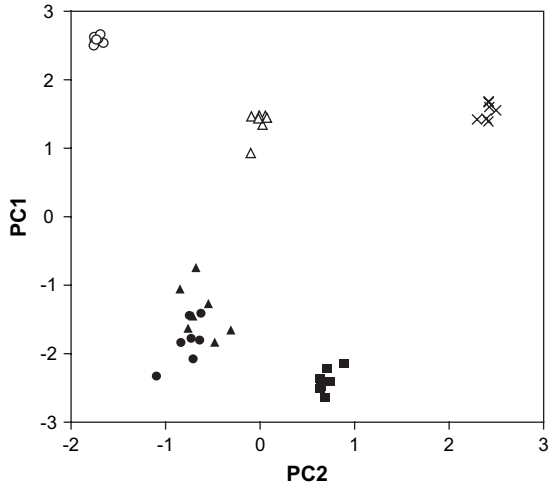


Fig. 3. PCA plot of sediment (percent coarse, medium, and fine sand, mud, organic content, penetrometer depth), and plant (percent leaf litter and algae) variables across six habitats. Habitats are denoted as: mangrove = solid squares (■), pneumatophore = solid triangles (▲), seagrass = solid circles (●), channel = exes (×), bank = open triangles (△), and sand flat = open circles (○).

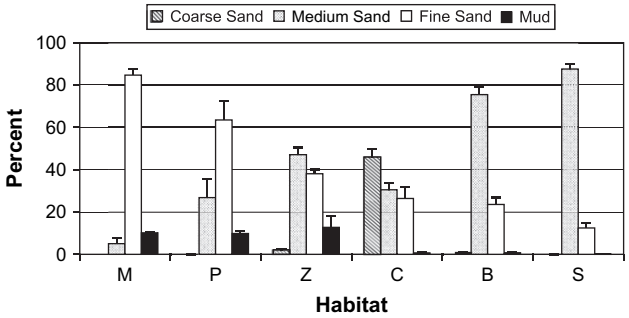
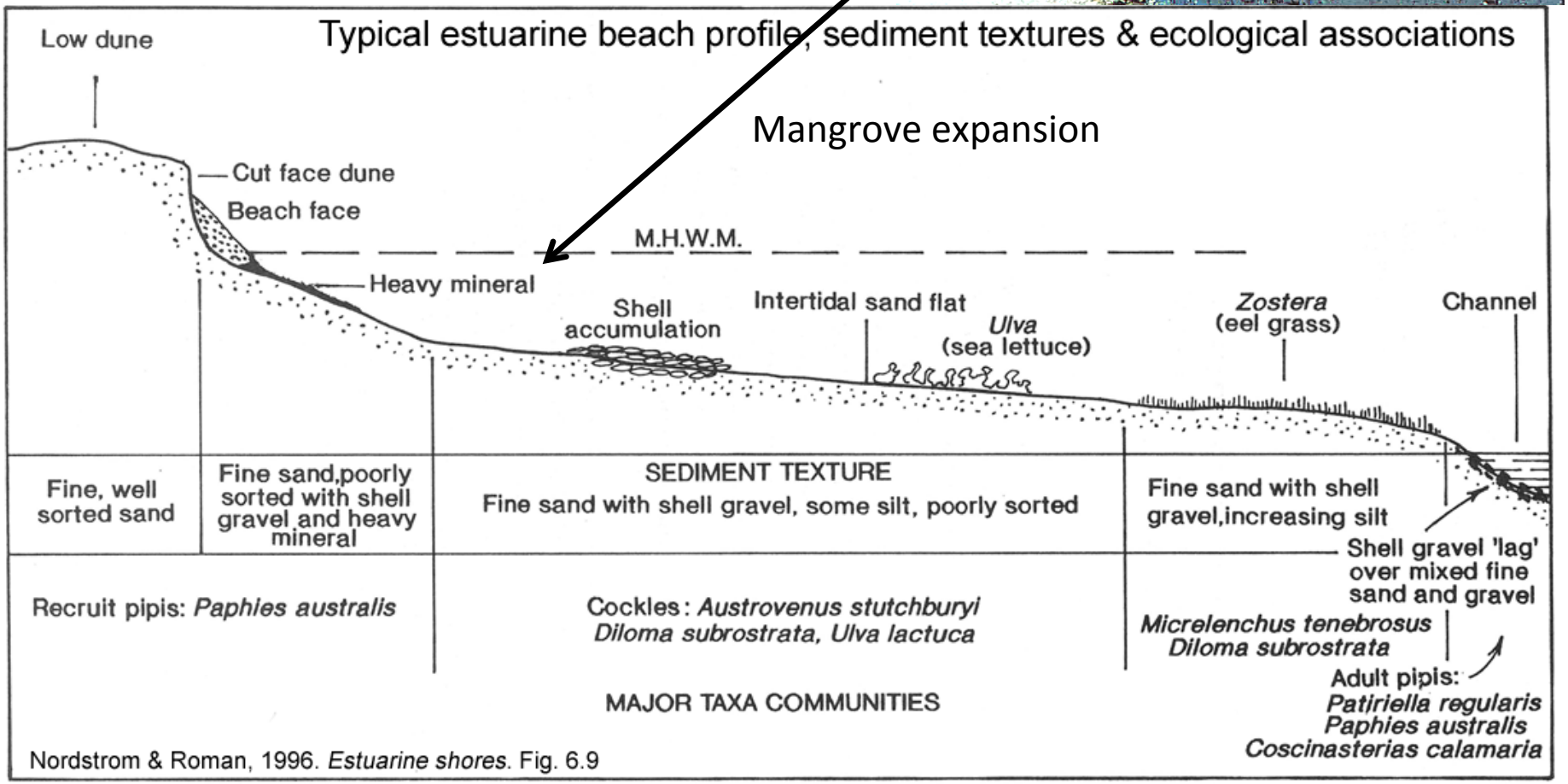


Fig. 2. Grain size analysis for sediments within various habitats (M = mangrove, P = pneumatophore, Z = seagrass, C = channel, B = bank, and S = sand flat) at Matapouri Estuary.

Alfaro, A. C. (2006). Benthic macro-invertebrate community composition within a mangrove/seagrass estuary in northern New Zealand. Estuarine, Coastal and Shelf Science, 66(1–2), 97–110. http://doi.org/10.1016/j.ecss.2005.07.024

NZ estuarine beaches

- Generally coarser than intertidal flat sediments



Seagrass habitat Biodiversity

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- Seagrass provides important fish habitat
  - Depends on location
- Suggested that it is less significant for southern NZ
  - But limited samples from very different estuarine systems

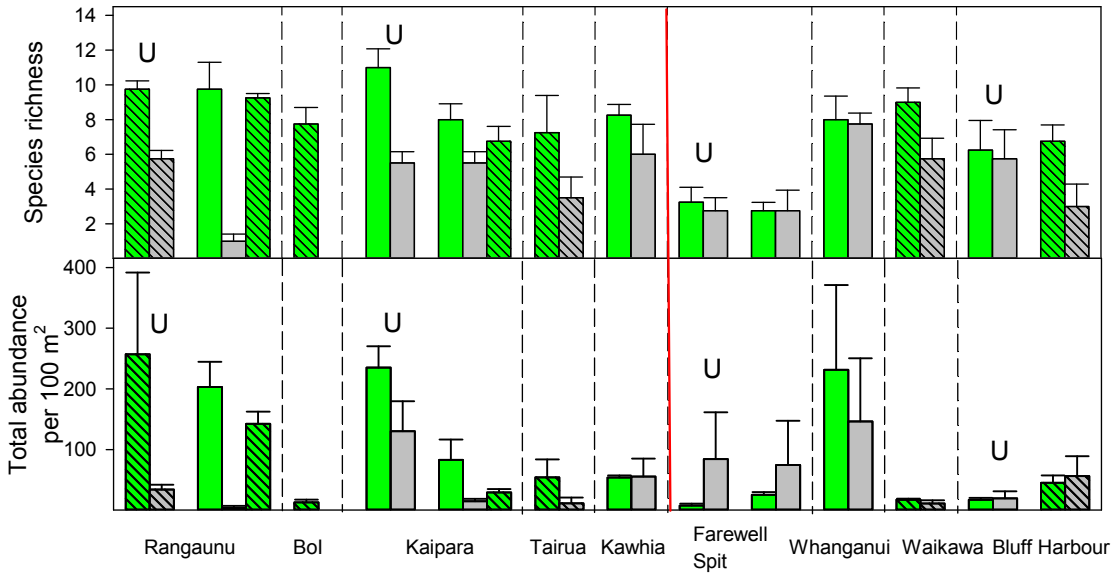

Figure 3: Species richness (top) and total abundance (bottom) of all fish species caught by beach seine from seagrass and sand habitats from nine locations in the North and South Island. U = upper harbour sites, all other sites are by default lower harbour sites. Green shading, seagrass; grey shading, bare sediments; hatching, subtidal, no-hatching, intertidal. Red line denotes break between North and South Islands.

Morrison *et al*, 2014. Seagrass Meadows as Biodiversity and Productivity Hotspots. New Zealand Aquatic Environment and Biodiversity Report No 137. MPI, Wellington

Mangrove & seagrass Biodiversity

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- Mangrove associated with reduced biodiversity & abundance
- Seagrass associated with increased biodiversity & abundance
  - Depends on location (& estuary type?)

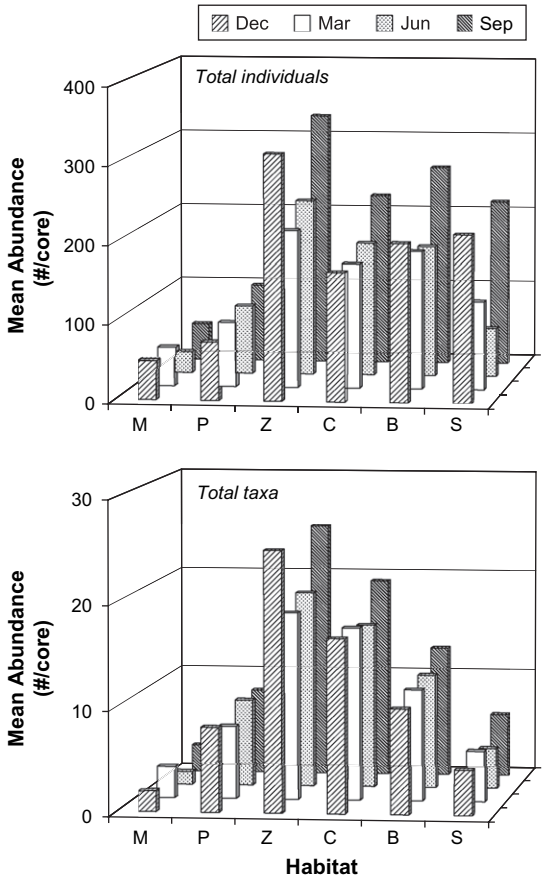
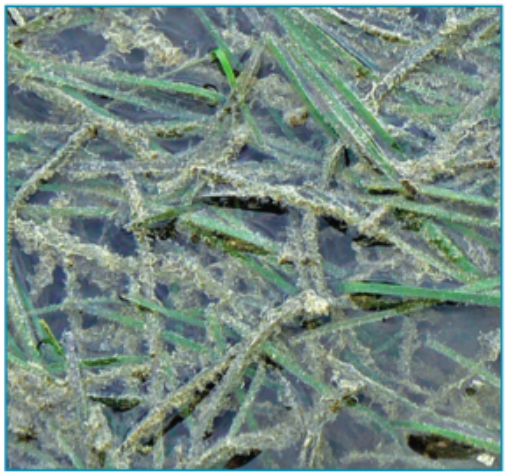


Fig. 4. Mean (±SE) number of individuals and taxa within six habitats (M = mangrove, P = pneumatophore, Z = seagrass, C = channel, B = bank, and S = sand flat) at Matapouri Estuary.

Alfaro, A. C. (2006). Benthic macro-invertebrate community composition within a mangrove/seagrass estuary in northern New Zealand. Estuarine, Coastal and Shelf Science, 66(1–2), 97–110. http://doi.org/10.1016/j.ecss.2005.07.024

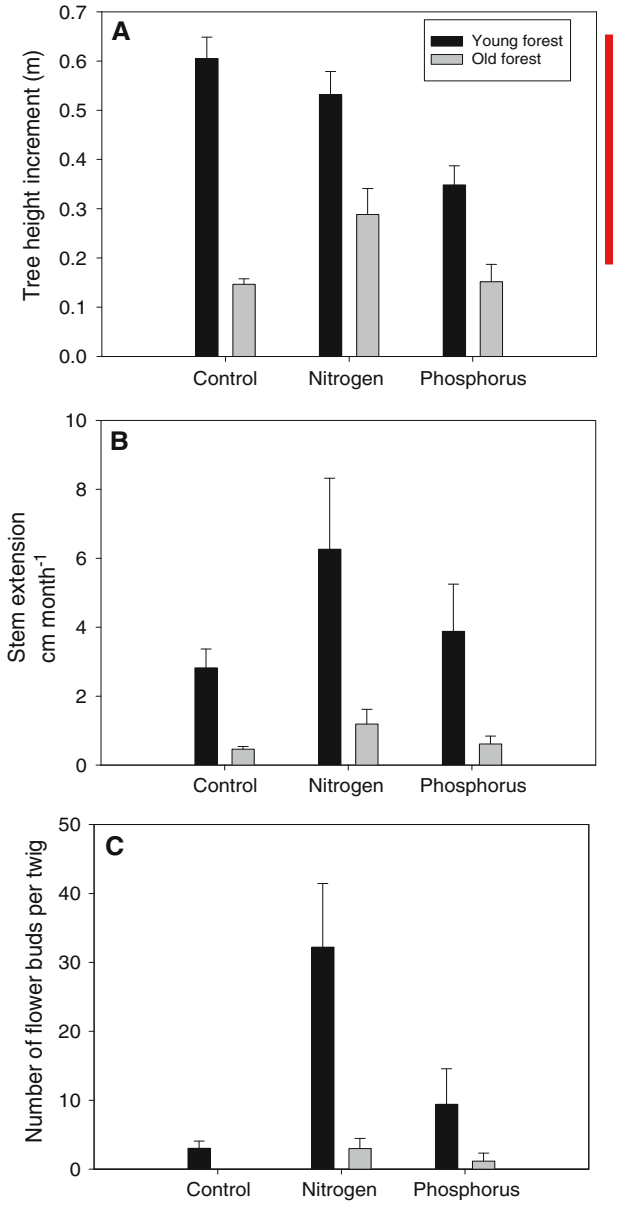
Nutrient response

- Fertiliser applications indicate that mangrove growth increased
- Conversely seagrass growth inhibited
  - Extra nutrients enhance algal growth that coats or shades blades of seagrass & reduces photosynthesis?



Seagrass with attached algae.
Photo: Fleur Matheson

Seagrass near Tauranga smothered by drifting sea lettuce.
Photo: Fleur Matheson



Lovelock *et al* (2010). Mangrove Forest and Soil Development on a Rapidly Accreting Shore in New Zealand. *Ecosystems* 13: 437–451 DOI: 10.1007/s10021-010-9329-2

Figure 6. Mean increments in tree height (**A**), mean stem extension (**B**), and mean number of flower buds per twig (**C**) from trees from a young forest (~10 years old, *solid bars*) and older forest (~30 years old, *gray bars*). Trees were fertilized with either nitrogen or phosphorus or unfertilized (*control*). Values are means and standard errors, $N = 6$.

Whangamata Estuary

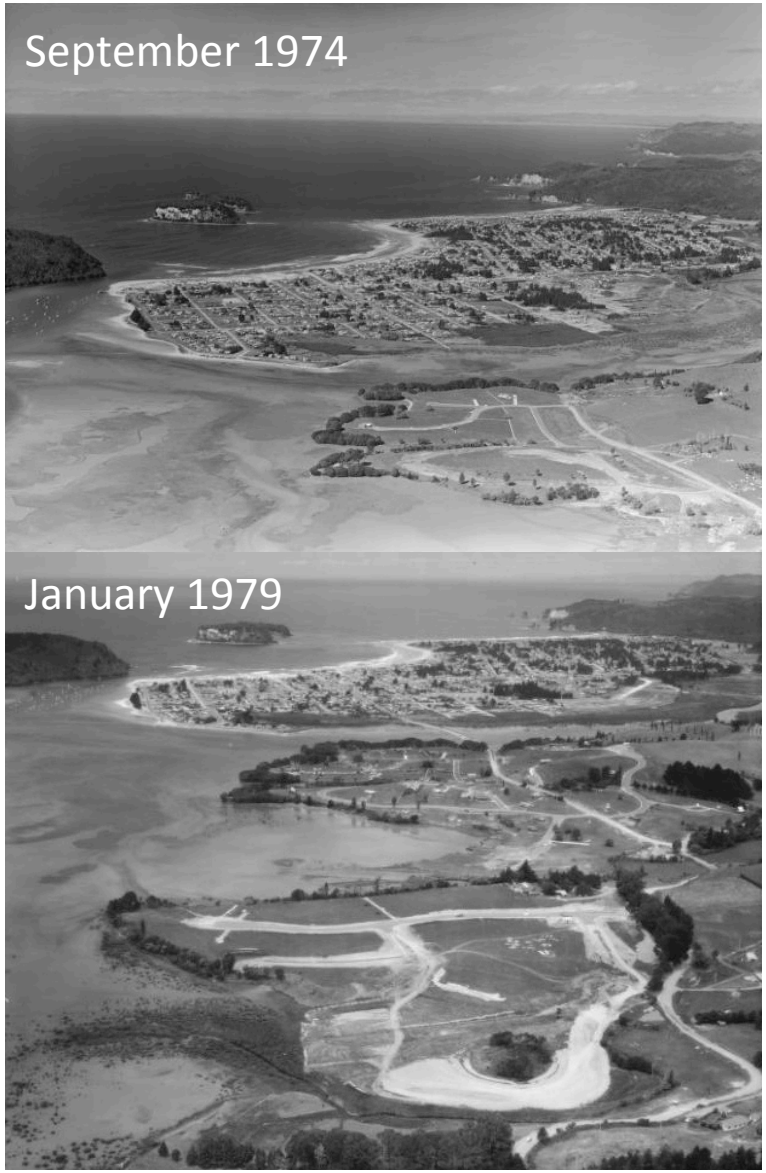
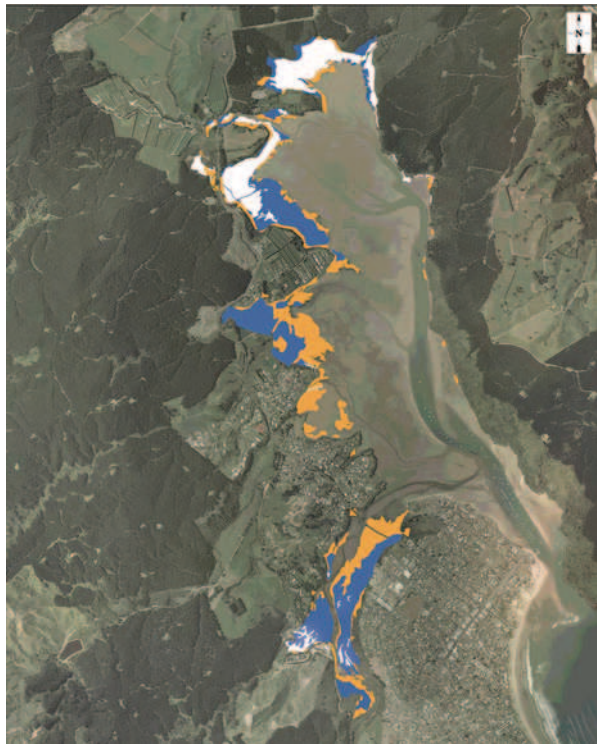


Fig. 1 Map demonstrating expansion of mangrove habitat based on aerial photographs for Whangamata Harbour, New Zealand. Mangrove extent is marked in *white*, *blue* and *yellow*, representing mangrove distributions in the Harbour in 1944, 1978 and 2002, respectively

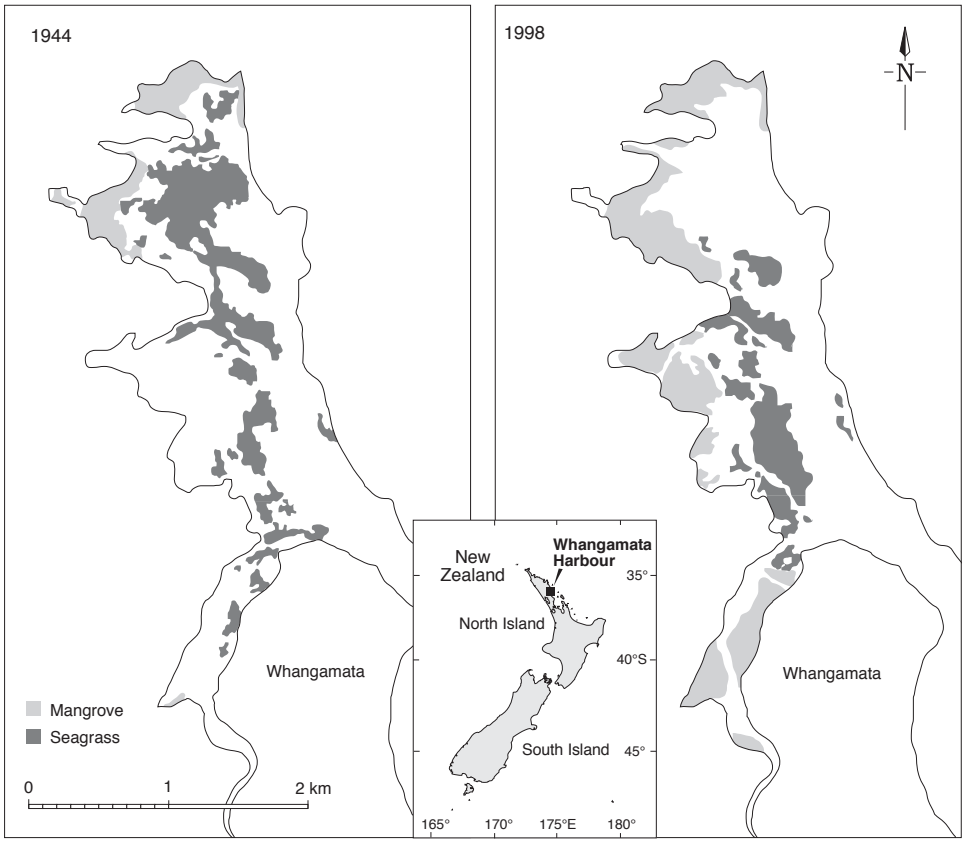


- Mangrove extent increasing since 1940s
- Fastest change associated with construction of Hetherington Rd causeway in 1976

Lundquist *et al* (2014). Managing mangrove habitat expansion in New Zealand. Faridah-Hanum et al. (eds.), Mangrove Ecosystems of Asia, 415 DOI 10.1007/978-1-4614-8582-7_19,

Whangamata Estuary

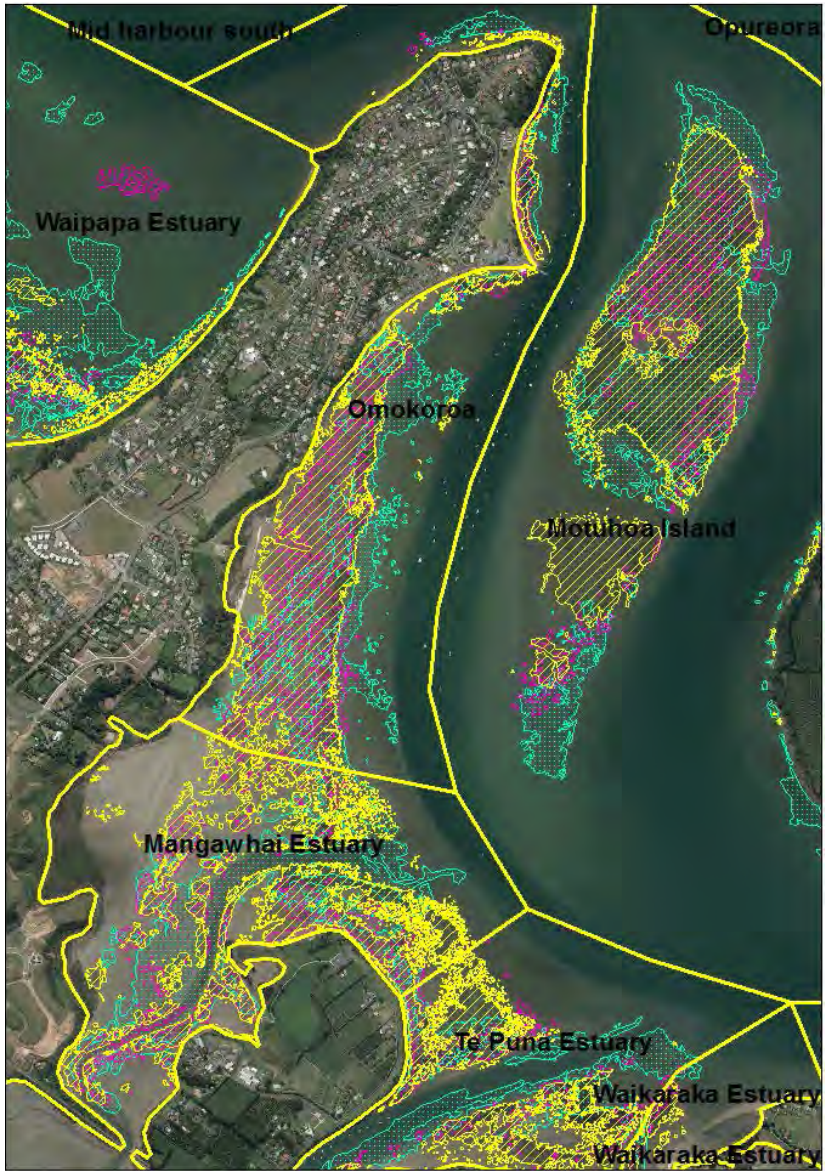
- Expansion of mangrove coincided with seagrass decline
- Caused by?
  - Increased sedimentation & turbidity
  - Increased nutrients (N & P)
  - Something else



Changes in the distribution and extent of seagrass and mangrove habitat in Whangamata Harbour between 1944 and 1998. Based on aerial images from Cawthron Institute (2000)

Turner & Schwarz, 2006. Management and conservation of seagrass in New Zealand: an introduction. Science for Conservation 264, DOC, Wellington.

Is seagrass declining?



BoPRC (2016).Environmental Publication 2016/03 – Extent of seagrass in the Bay of Plenty in 2011 Seagrass extents in 1959 (aqua), 1996 (purple) and 2011 (yellow)

Some estuaries previously identified as having declining seagrass coverage have observed an increase recently

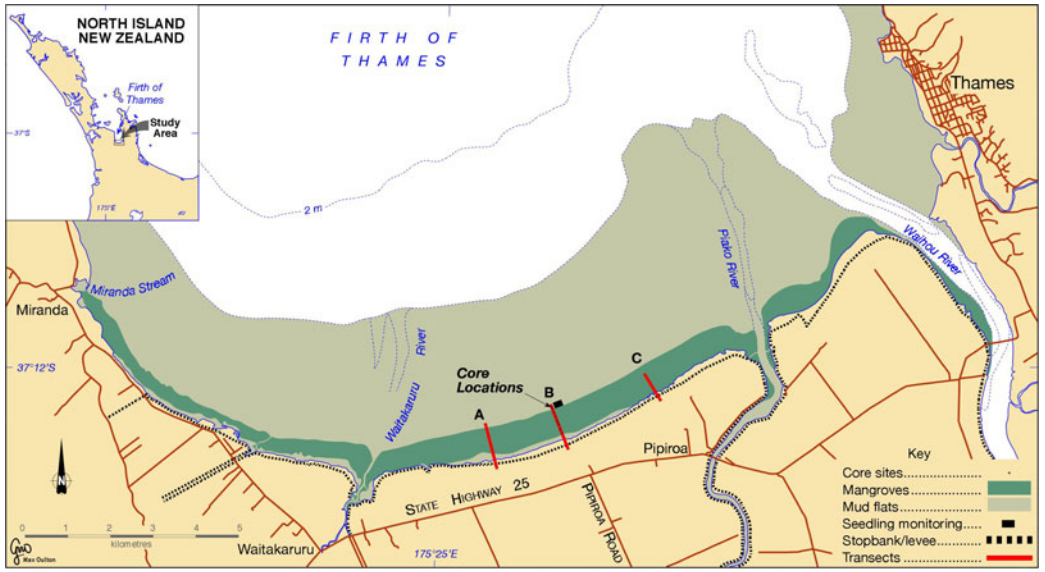
- Tauranga Harbour, particularly “urban” areas
- Whangarei Harbour, including restored areas
- Raglan Harbour
- Kawau Bay

Millon Bay

- Coastal embayment within Kawau Bay
- Some coastal restoration work underway
- Mangrove extending onto tidal flats partially removed
- Seagrass expanding rapidly since 2010

Mangrove expansion

- Hauraki Plains Act 1908
  - Initiated construction of stopbanks, drains & canals to develop low lying swamps of Hauraki Plains
  - Partly in response to flooding of Waihou River linked to discharge of mine tailings from Ohinemuri River
- Due to low gradients flows predominantly tidal, requiring installation of pumping stations



Swales *et al* (2007). Sediment Processes and Mangrove-Habitat Expansion on a Rapidly-Prograding Muddy Coast, New Zealand. Coastal Sediments '07. Sixth International Symposium on Coastal Engineering and Science of Coastal Sediment Process, ASCE

Where does the sediment come from?

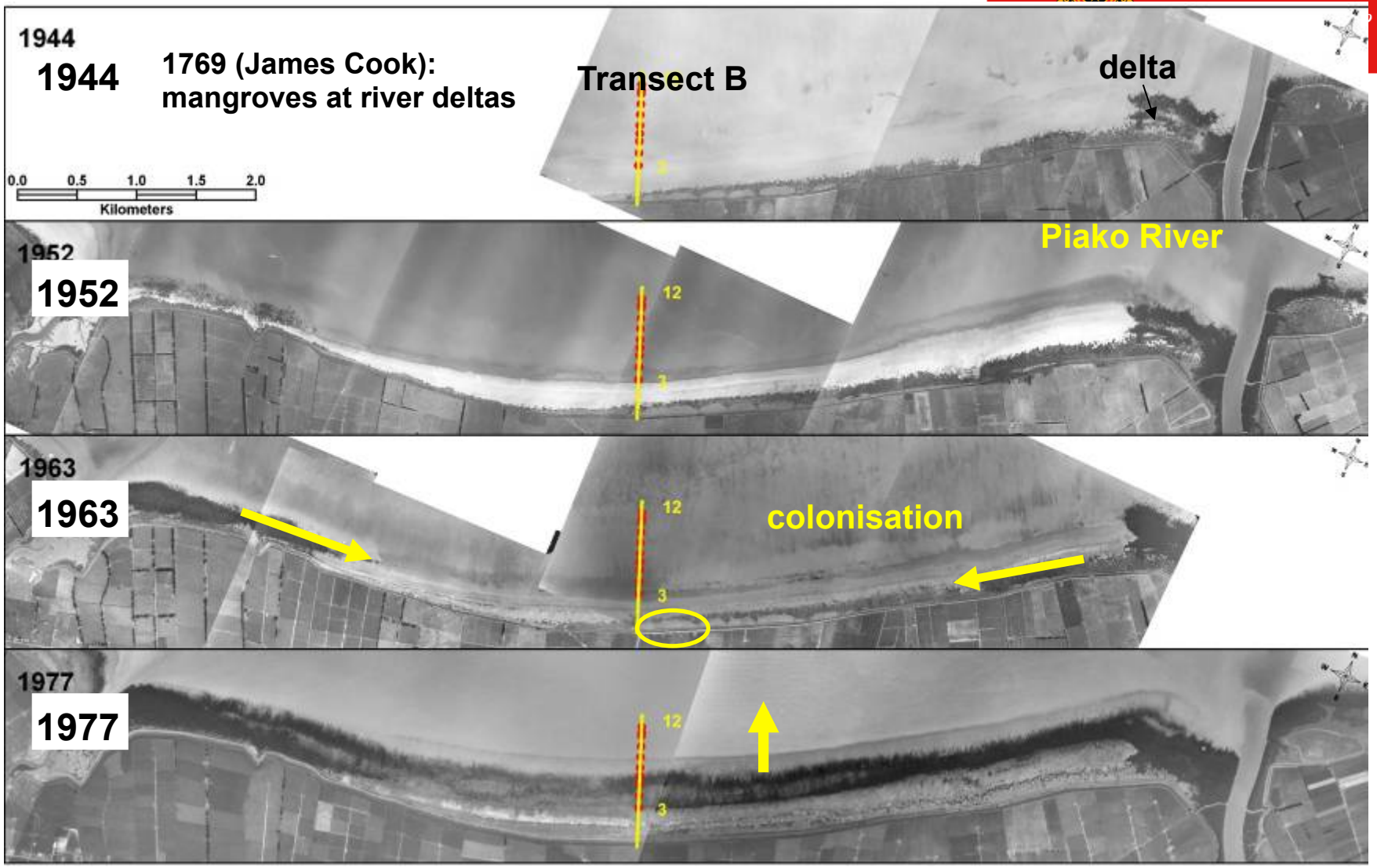
1938 storm surge

- May 1938 largest historical storm surge flooded large area of Hauraki Plains
- Resulted in construction of coastal stopbanks from Miranda to Thames
  - Prevented deposition of silts on coastal plains during high tides & storm surges

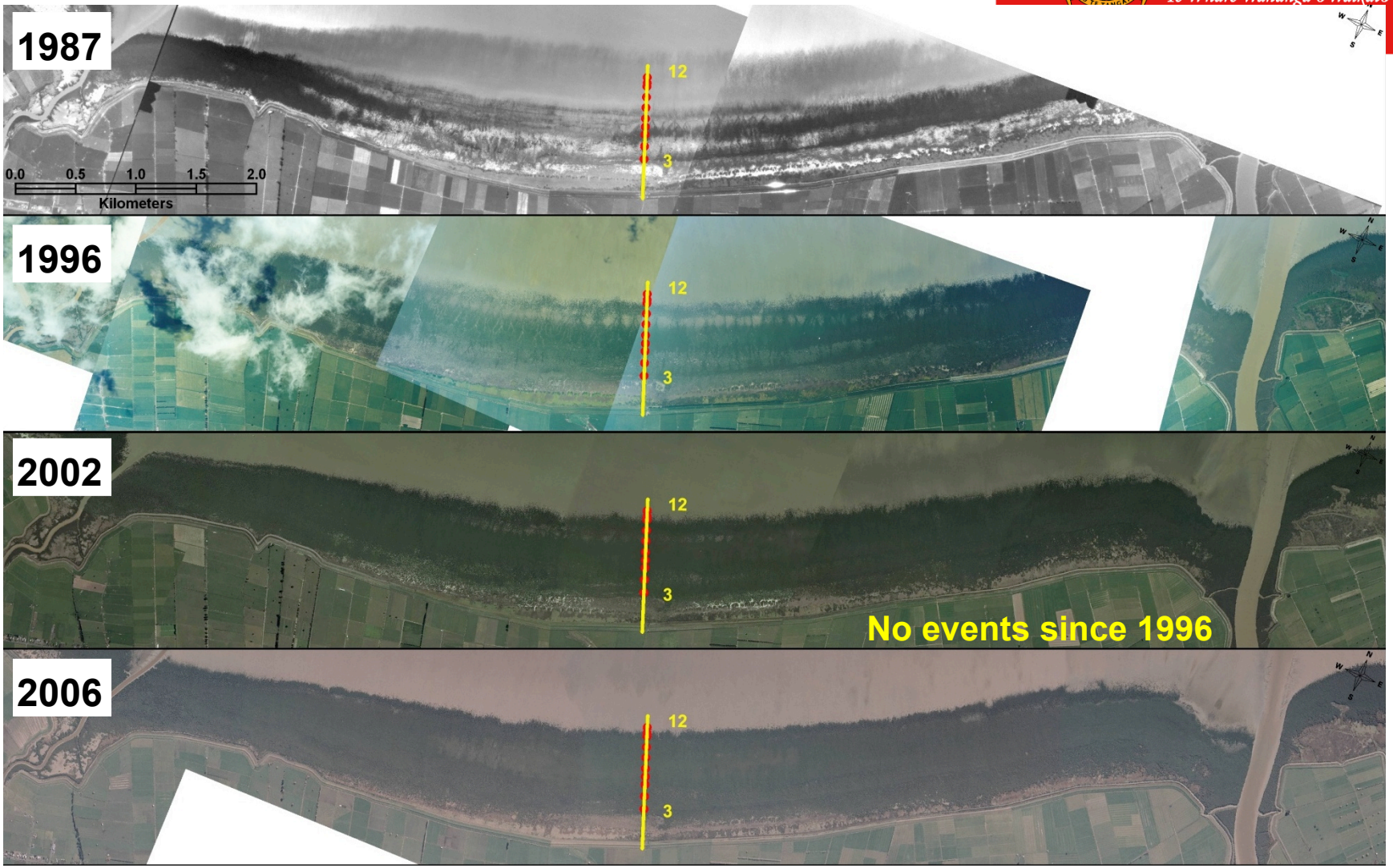
Seawater flooding of the Hauraki Plains in the aftermath of the May 1938 storm. View looking west towards the Waitakaruru River. Piako River in the middle of the photo (source: Hauraki Catchment Board files, Environment Waikato Paeroa office).

Mangrove-Habitat Expansion in the Southern Firth of Thames: Sedimentation Processes and Coastal-Hazards Mitigation. Environment Waikato Technical Report 2008/13

Mangrove-habitat expansion: 1944 - 1977



Mangrove-habitat expansion: 1987- 2006

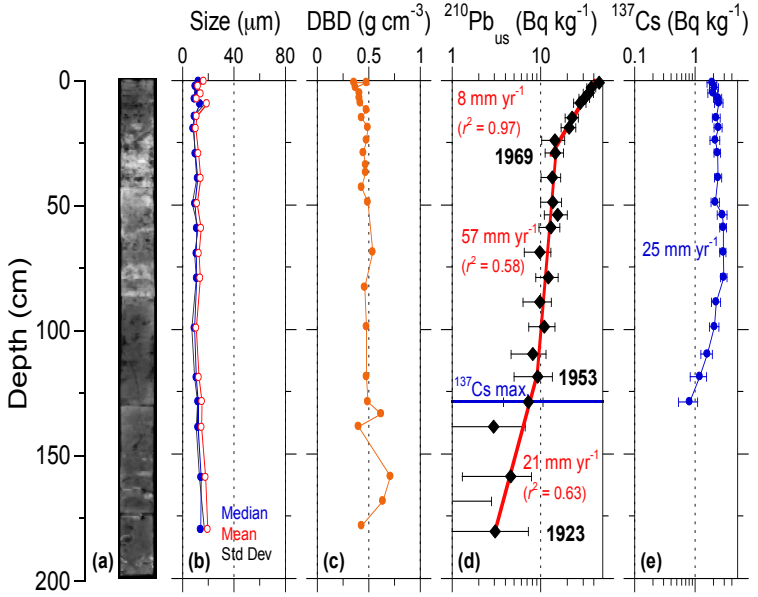


Appletree Research Site

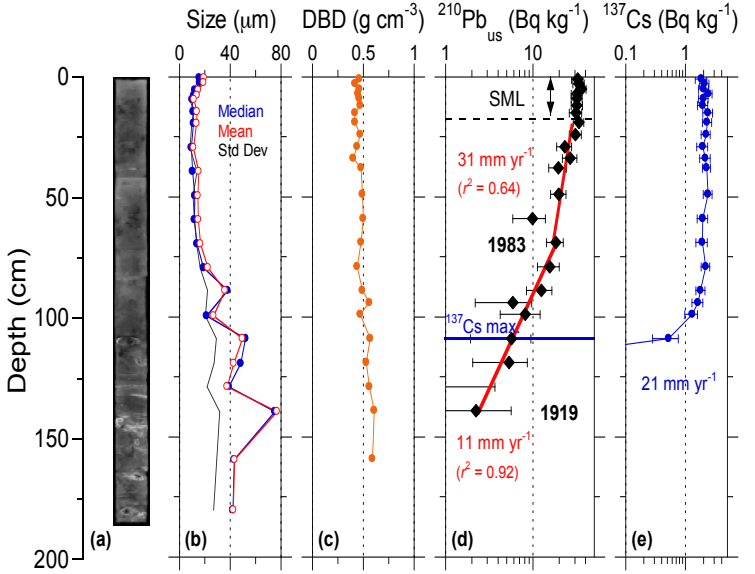
- Southern Firth of Thames
- Sediment accumulation rates determined by isotope studies using Pb, and Cs, plus pollen studies
- Supported by X-ray & Be analysis to help determine surface mixing depth
- Mud accumulation predated mangrove expansion

The Firth of Thames is under increasing pressure from people's activities

Swales *et al* (2007). Sediment Processes and Mangrove-Habitat Expansion on a Rapidly-Prograding Muddy Coast, New Zealand. Coastal Sediments '07. Sixth International Symposium on Coastal Engineering and Science of Coastal Sediment Process, ASCE



Old Growth Mangrove forest

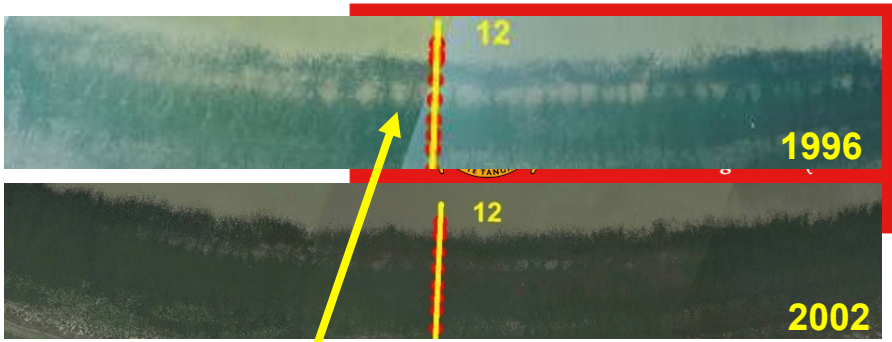


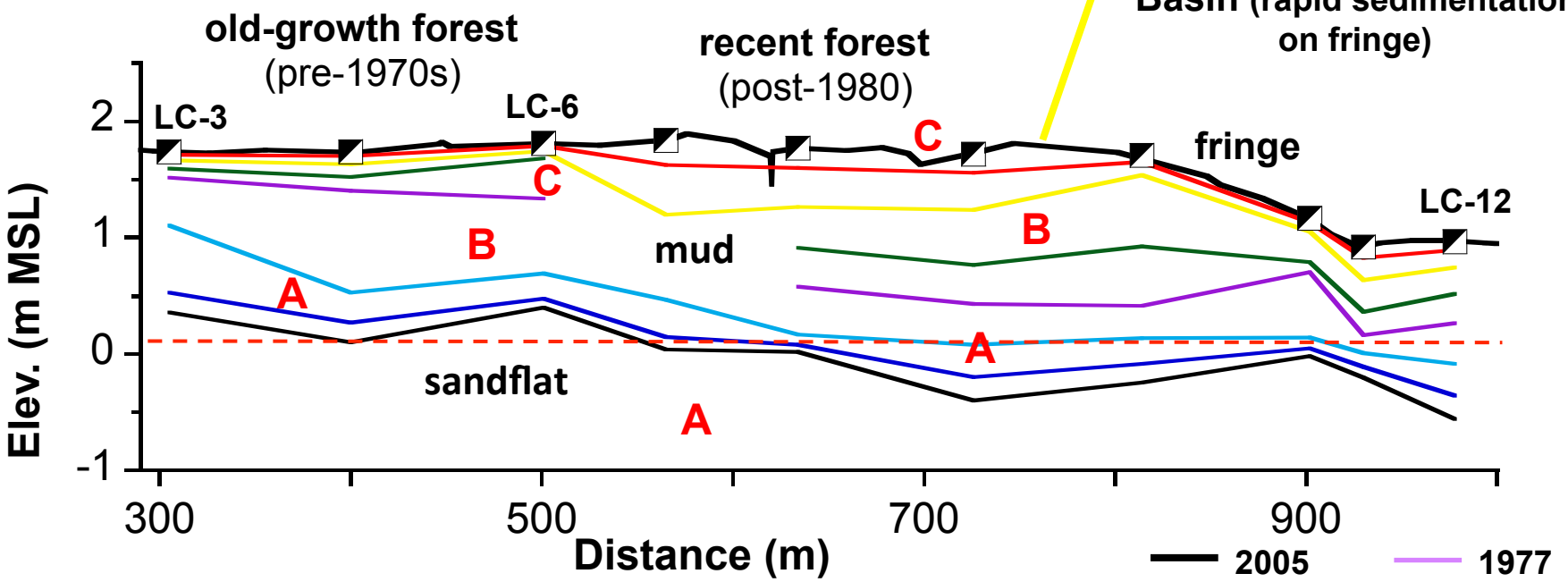
Mangrove fringe

Tidal-flat evolution

A tale of two forests

Source: Swales et al 2007





Transition: sandflat to mudflat (1940s)
old-growth forest: reduced SAR last 30 yrs
recent forest: rapid SAR to present, internal **basin infills**
Complex geomorphic evolution

A: mudflat/sandflat
B: fringe
C: mature forest

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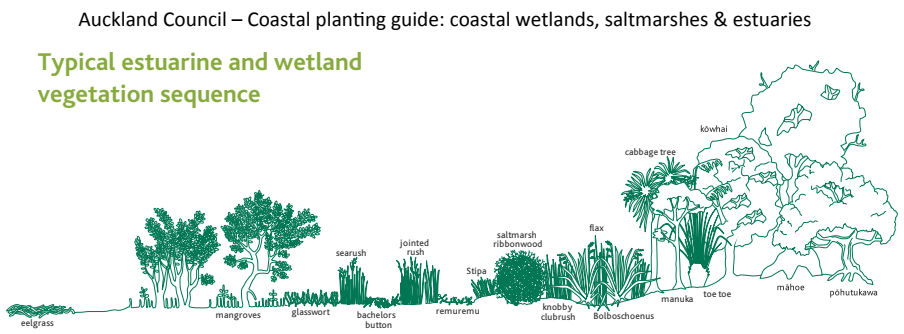
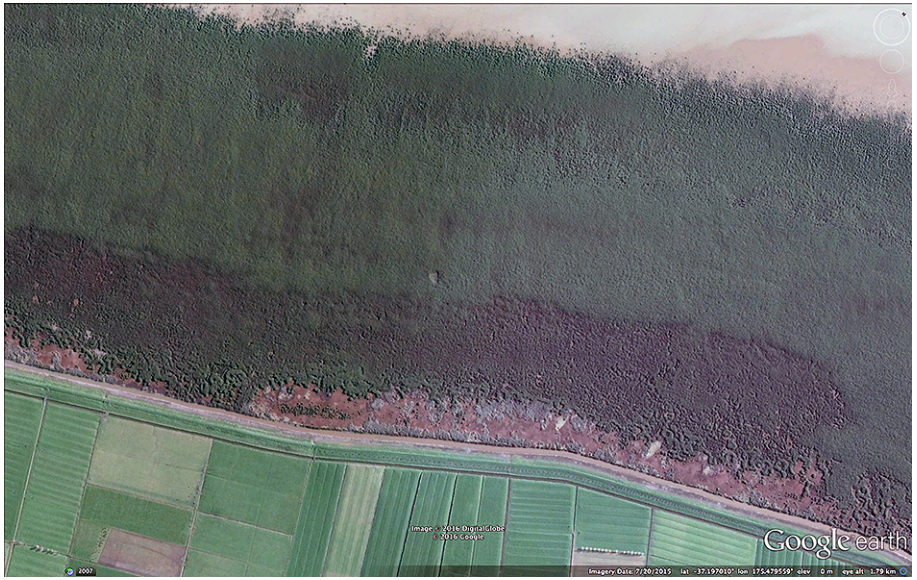
SAR = Sediment Accretion Rate

Loss of salt marsh

- Construction of dykes or stopbanks are recognised as a cause of salt marsh loss
- Mangrove do not appear to be able to compete with well established salt marsh
- Salt marsh effectively traps fine sediment & nutrients
  - Similar to fluvial wetlands
- Perhaps concentrated zone of sedimentation in southern Firth of Thames is due to recirculation & loss of salt marsh?

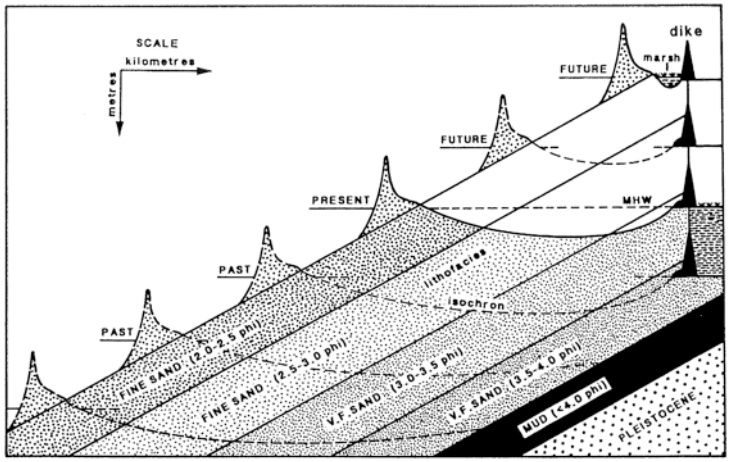
Auckland Council – Coastal planting guide: coastal wetlands, saltmarshes & estuaries





Back-barrier sedimentation Wadden Sea

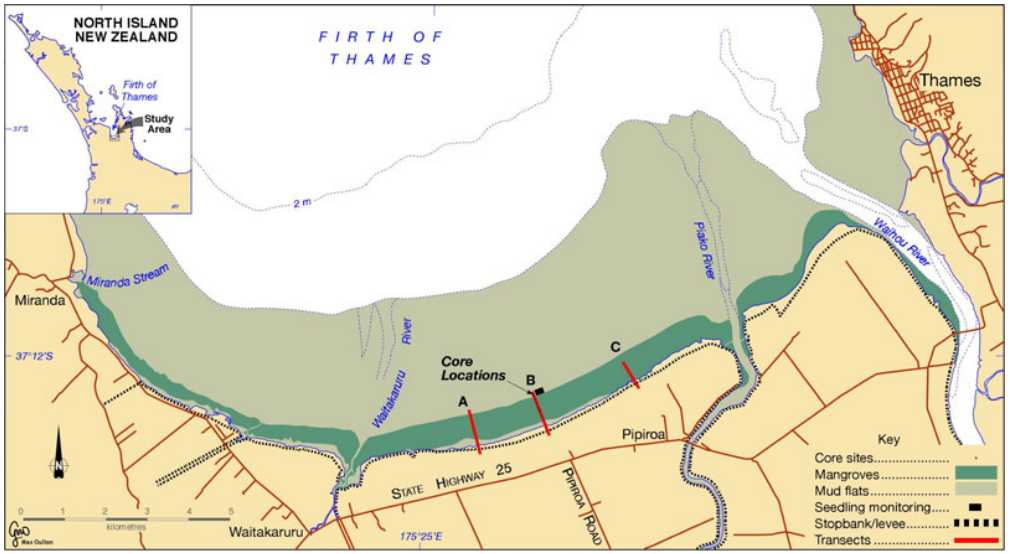
- Construction of dykes (stopbanks) changed sedimentation patterns within Wadden Sea
  - Loss of upper intertidal area where fine sediment accumulated
  - Required for dyke construction
- Additional structures built in front of dykes to trap silts
  - Creating salt marsh habitat



Fleming & Nyandwi, 1994. Netherlands Journal of Aquatic Ecology 28(3-4): 299-307

Coastal realignment

- An alternative approach is to relocated dykes further inland, & allow tidal flooding to reoccur



Conclusion

- Mangrove & seagrass distributions do reflect general condition of an "estuary"
- However
  - Estuaries are very variable
  - Interactions between flora & processes not well understood
  - Distribution of seagrass is poorly defined
- Cannot really use them to predict estuarine state

Possible causes of seagrass decline