A long view – the impacts of humans on New Zealand marine ecosystems since first settlement

Alison MacDiarmid and Matt Pinkerton

NIWA, Wellington

Multi-disciplinary team from 14 institutions addressed what, when, where, and why

- Drew Lorrey – climatologist
- Bruce McFadgen – geologist
- James Goff – sedimentologist
- Catherine Chagué-Goff – geologist
- Helen Neil – paleontologist
- Peter Marriot – micro-milling
- Peter Horn – fish aging
- Foss Leach – archaeologist
- Ian Smith – archaeologist
- Bruce Stirling – historian
- Phillip Cleaver – historian
- Kimberley Maxwell – oral historian
- Larry Paul – fisheries historian
- Reese Richards – sealing and whaling historian
- Tim Smith – whaling historian
- Scott Baker – cetacean biologist
- Emma Carroll – cetacean ecologist
- Nathalie Patenaude – cetacean ecologist
- Jennifer Jackson – cetacean geneticist
- Liz Slooten – cetacean ecologist
- Elenor Hutchison – cetacean ecologist
- John Zeldis – biological oceanographer
- Jenny Beaumont – benthic ecologist
- Emma Jones – benthic ecologist
- Mark Morrison – benthic ecologist
- Darren Parsons – marine ecologist
- Malcolm Francis – fisheries and sharks
- Chris Lalas – seabird and seal ecologist
- David Thompson – seabird ecologist
- Chris Francis – fisheries modeler
- Andy McKenzie – fisheries modeler
- Divya Varkey – fisheries modeler
- Matt Pinkerton – ecosystem modeler
- Jeanie Stenton-Dozey – ecosystem modeler
- Caroline Lundquist – ecosystem modeler
- Ed Abraham – ecosystem modeler
- Tony Pitcher – modelling and advice

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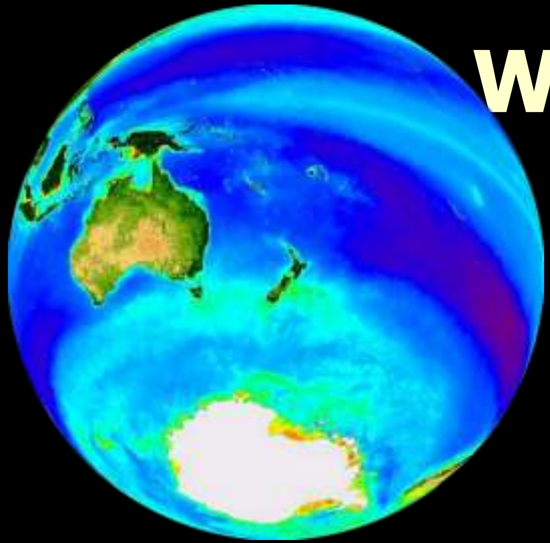
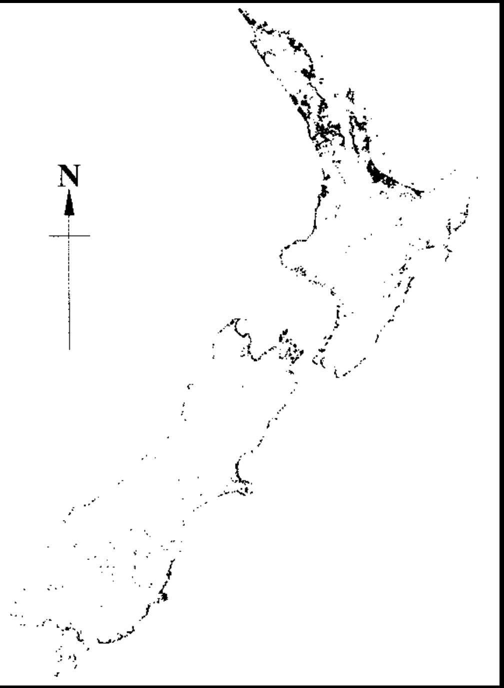
Why ask this question here?





New Zealand archaeological sites containing midden (n > 20,000) show a strong coastal bias. Data NZ Archaeological Association

NZ isolated in SW Pacific

Humans settled late (~1250 AD) when sea levels had stabilised long after the most recent ice age.

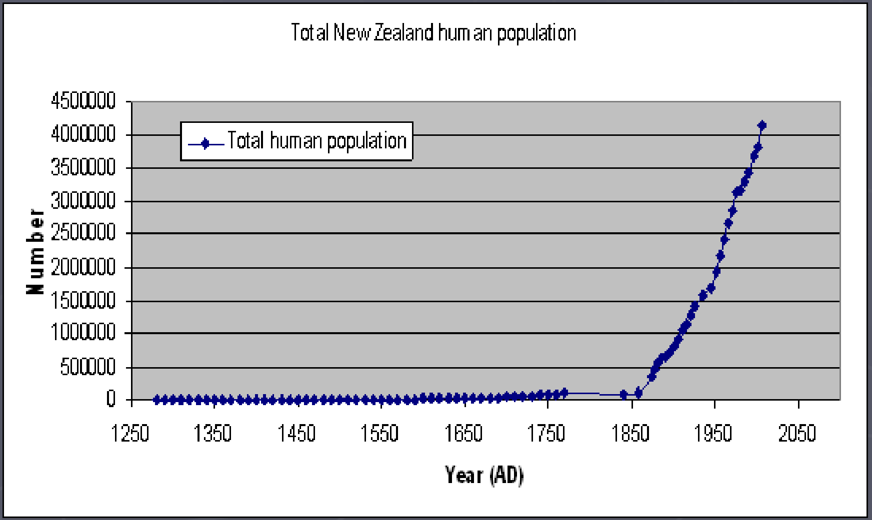
Consequently NZ has a short and reasonably complete and unbroken archaeological, historical and contemporary record of human exploitation of marine resources.

From a global perspective this is unusual.

Most other places have been inhabited for tens of millennia where the earliest evidence of human impacts on marine ecosystems is difficult to discern because of large fluctuations in climate and changes in sea level.

NZ is also highly unusual as we have reasonable estimates for the human population since first settlement

- Humans settled late ~1250AD
- Mitochondrial DNA evidence suggests the founding Polynesian population comprised ~70 females out of a total of about 200-300 persons
- Pool (1991) used a head count undertaken by James Cook to estimate a Māori population in 1769 of 86 000 - 100 000
- 2000 Europeans in NZ in 1840 at time of signing of the Treaty of Waitangi
- Regular census data have been collected since 1874
- This morning the NZ population is 4,495,846 according to Statistics NZ population clock



This information critical for estimating early marine resource use

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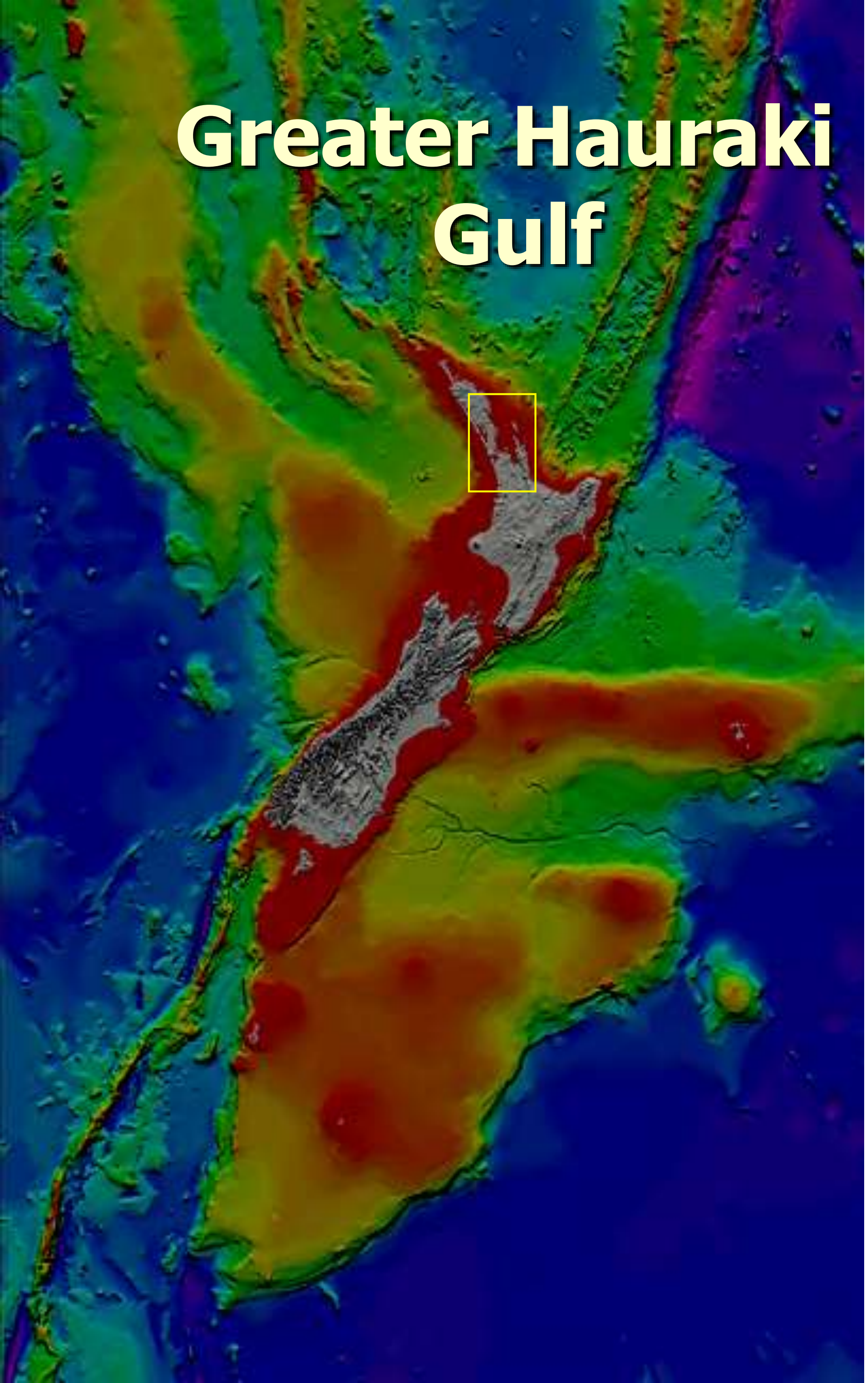
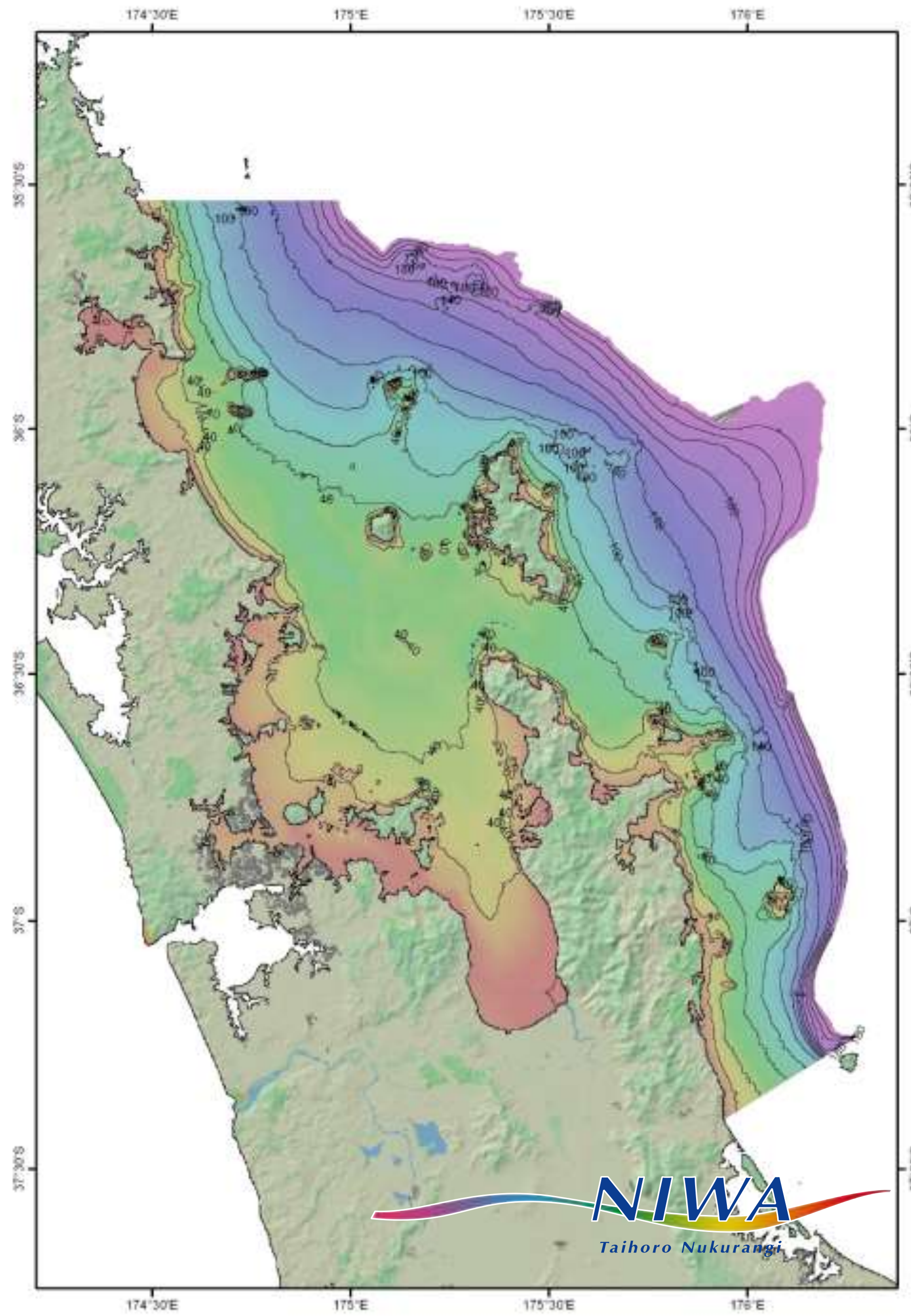
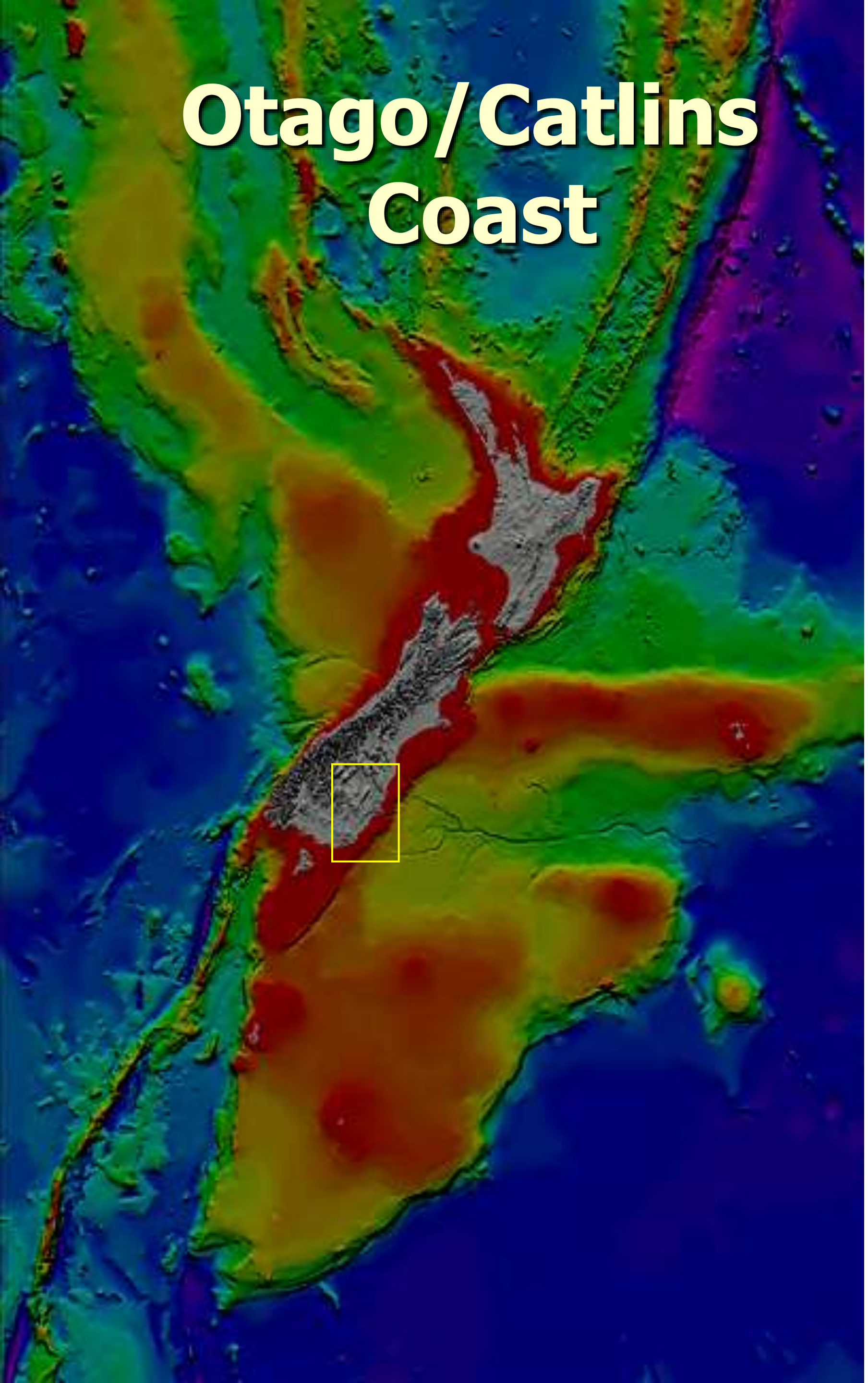
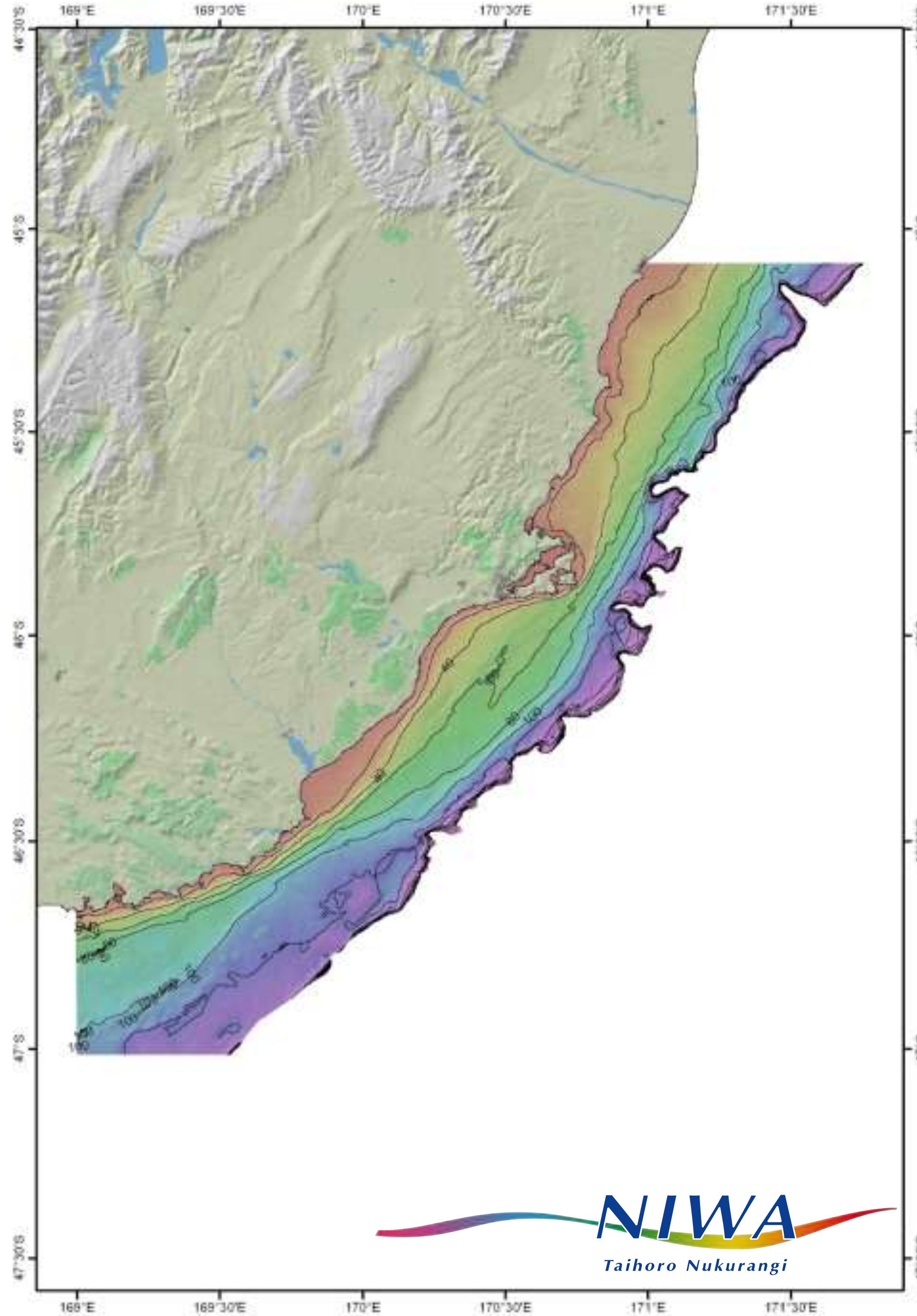
Greater Hauraki Gulf





Otago/Catlins Coast





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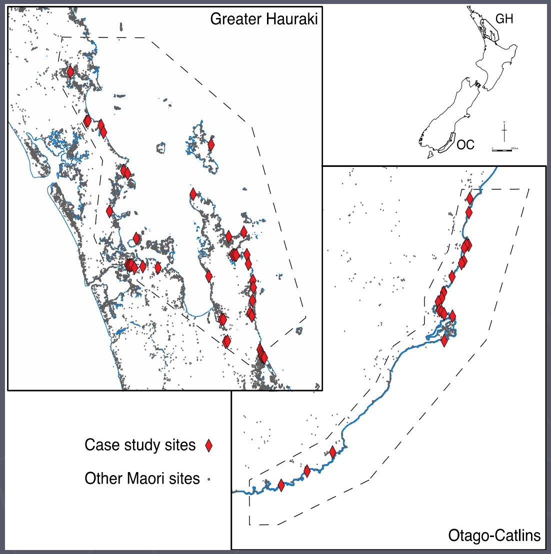
Pre-European Māori were sophisticated hunters and fishers

- Polynesians brought with them a well developed fish capture technology that they adopted to local conditions.
- As well as using a variety of hooks and traps to capture fishes Māori also developed enormous nets made of fibers derived from the NZ flax.
- By the time of Cooks arrival in 1769 this was an advanced technology with nets up to several hundred metres long (perhaps up to 1 km) and 10 m deep.
- Used as enormous beach seines requiring hundreds of people to deploy them.

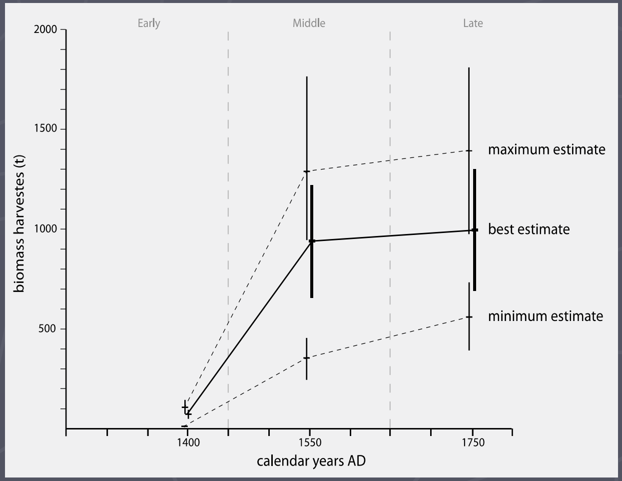
Estimating annual removals (numbers and biomass) of marine species by pre-European Māori is possible

By combining estimates of:

- The marine component of the human diet from published stable isotope analysis of human remains from different periods
- Māori population size
- Daily human calorific needs
- Midden composition



Prof. Ian Smith estimated minimum and maximum removals using the extremes of the above estimates as well as best estimates based on the average of individual estimates +/- 70% error



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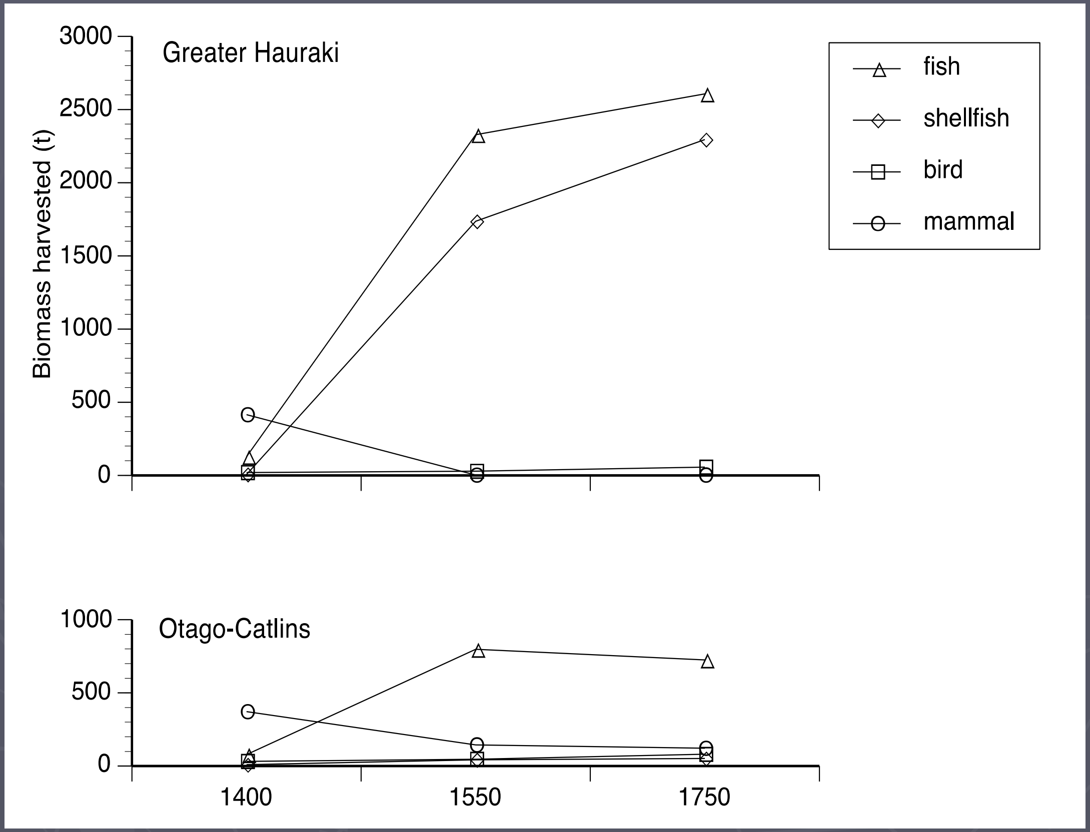
Change in key species harvested by pre-European Māori



Data for 101 taxa

- 46 shellfish
- 28 fish
- 22 birds
- 5 mammals

- Extirpation of fur seals and sea lions from northern NZ sometime before 1500AD
- Reduction in reliance on mammals in southern NZ
- Increased reliance on fish and shellfish

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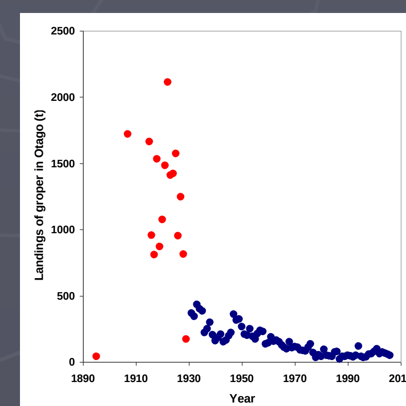
Historical sources indicate effects of European exploitation throughout 19th century

- The abundance of fish, invertebrates, and whales was remarkable to the earliest European visitors and explorers.
- By the mid-1840s European exploitation had largely extirpated fur seals, sea lions and southern right whales from coastal mainland NZ.
- This was followed by increasing exploitation of a range of fish and invertebrates once commercial fisheries were established in the 1860s to supply a growing European settler population and later rapidly developing export markets.
- For many of the principal exploited species in both study regions, noticeable declines in abundance occurred in the late 19th century and early 20th century prior to the statistical era that began in the 1930s.
- The historical narratives indicate that the declines were first evident in species such as rock oysters, grey mullet and flat fishes in sheltered, shallow, easily accessible areas, but later progressed to species with a wider inshore distribution such as snapper and blue cod, or a deep water refuge such as groper.



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The statistical era began in the 1930s

- Management of marine resources was greatly impeded by a lack of consistently collected fisheries landings data.

- By 1930, the collection of data for Auckland, at least, appears to have improved.

- Finally, in January 1935, a scheme for obtaining monthly returns of fish landed from every licensed fishing-boat in NZ was commenced. In his annual report for the year ending 1937, Chief Fisheries Inspector Hefford stated: '*For the first time in the history of the Department we have obtained data that may properly be called statistical*.'

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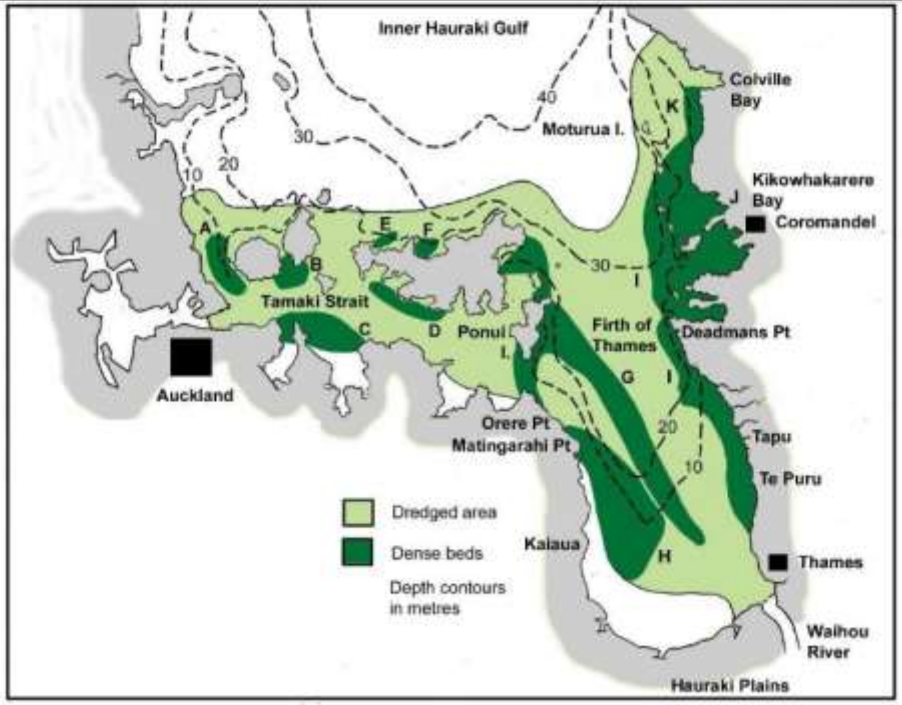
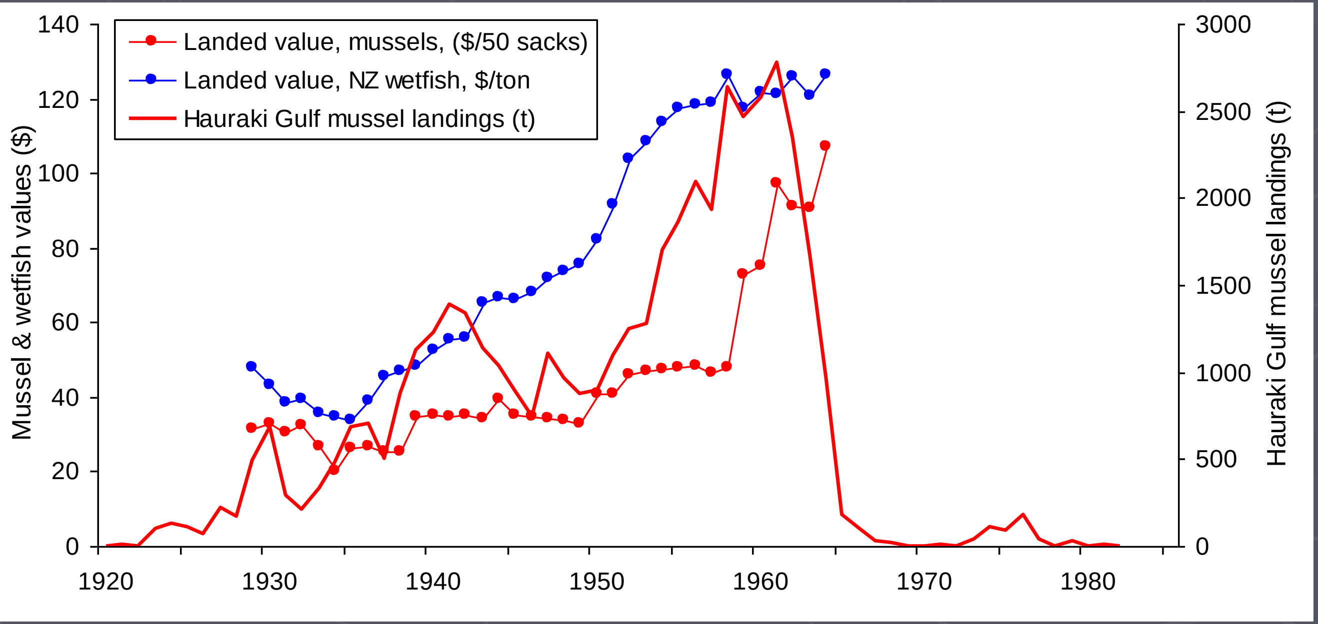
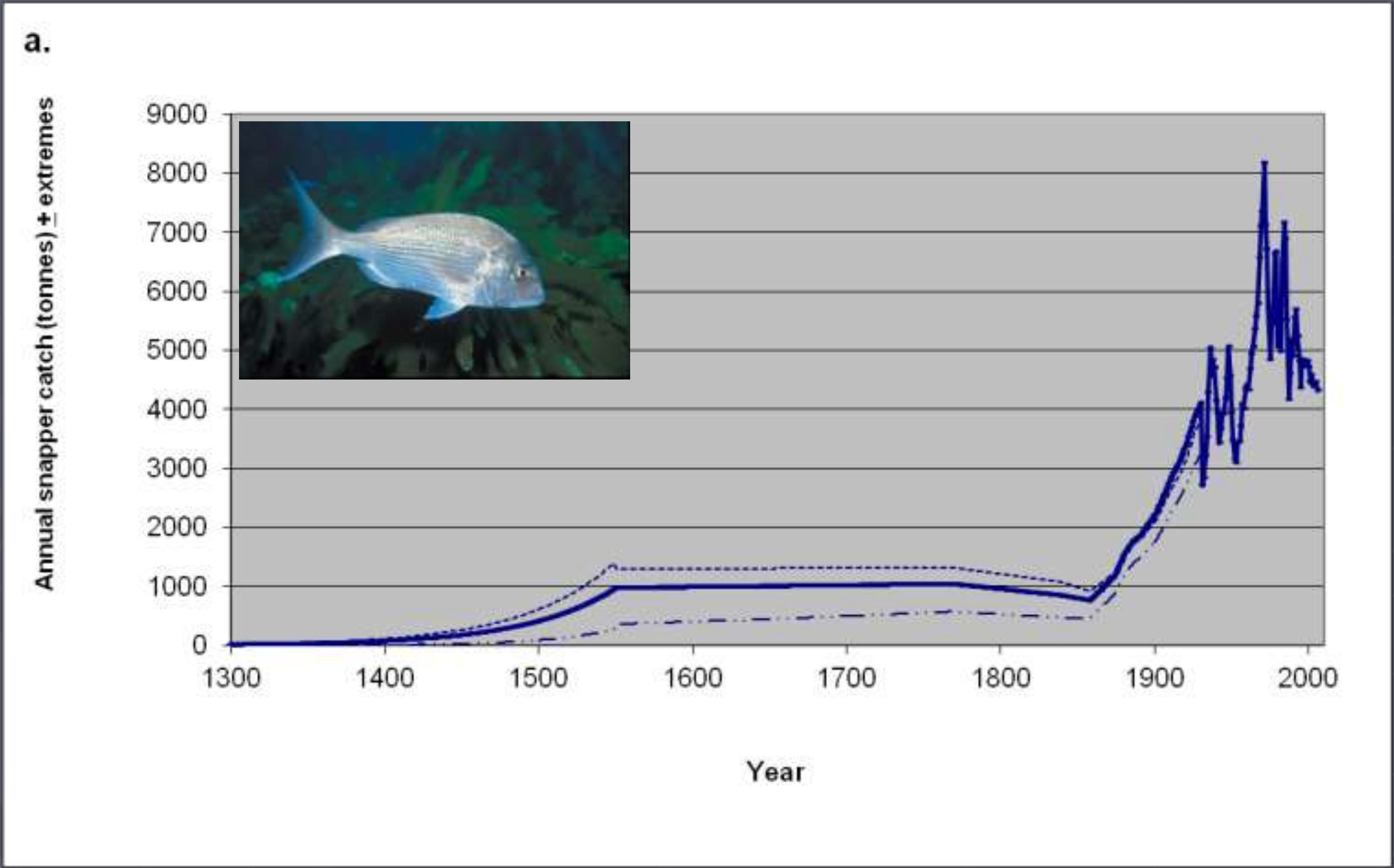
However, good management requires more than landing statistics – e.g. the collapse of the Thames green mussel dredge fishery





(From Paul 2012)

Other species are more resilient - annual catch of snapper in the Hauraki Gulf since human settlement



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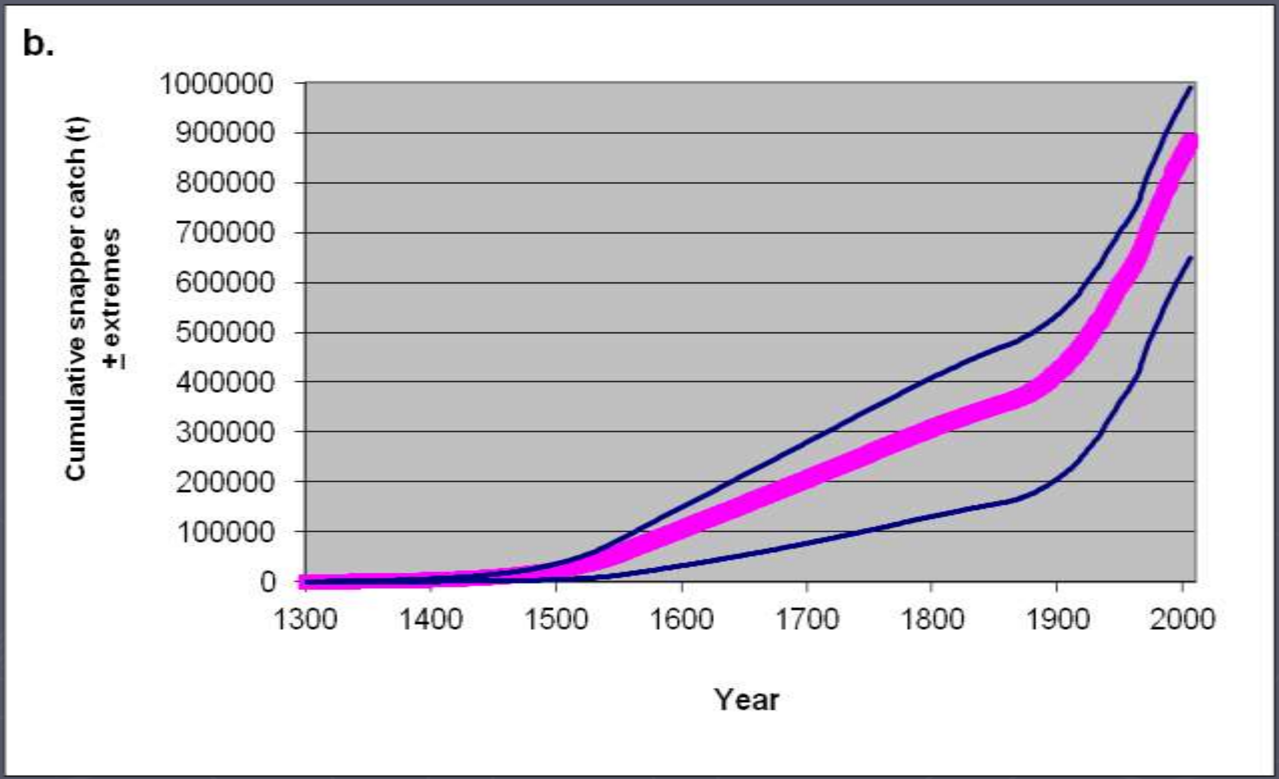
Cumulative catch of snapper in the Hauraki Gulf



- Overall humans have removed about 0.9 M tonnes of snapper from the ecosystem since first settlement
- Half in the period over 650 years to 1910
- Half in the last 100 years

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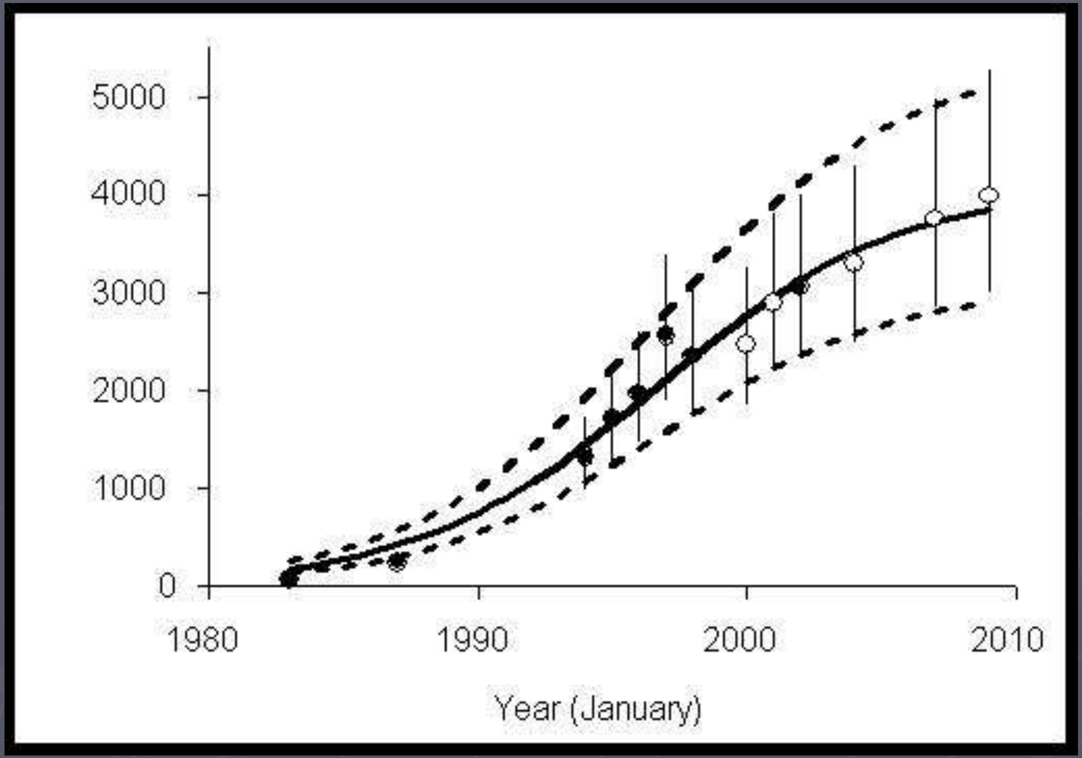
Some species are recovering

Annual pup production



Recovery of fur seals on Otago/Catlin coast from Lalas et al. unpublished data

- Annual pup production. Symbols indicate best estimates (vertical bars delineate lower and upper estimates) from 13 years with comprehensive surveys; all breeding sites were surveyed for eight years (solid circles) but some sites were missed in five years (open circles). Logistic model curve for best estimate (solid line) is flanked by lower and upper estimates (dotted lines).
- A logistic growth model applied to 13 estimates for annual pup production indicated that this population is now at about 95% of an asymptote of 19,000 individuals (plausible range 12,500-28,000)

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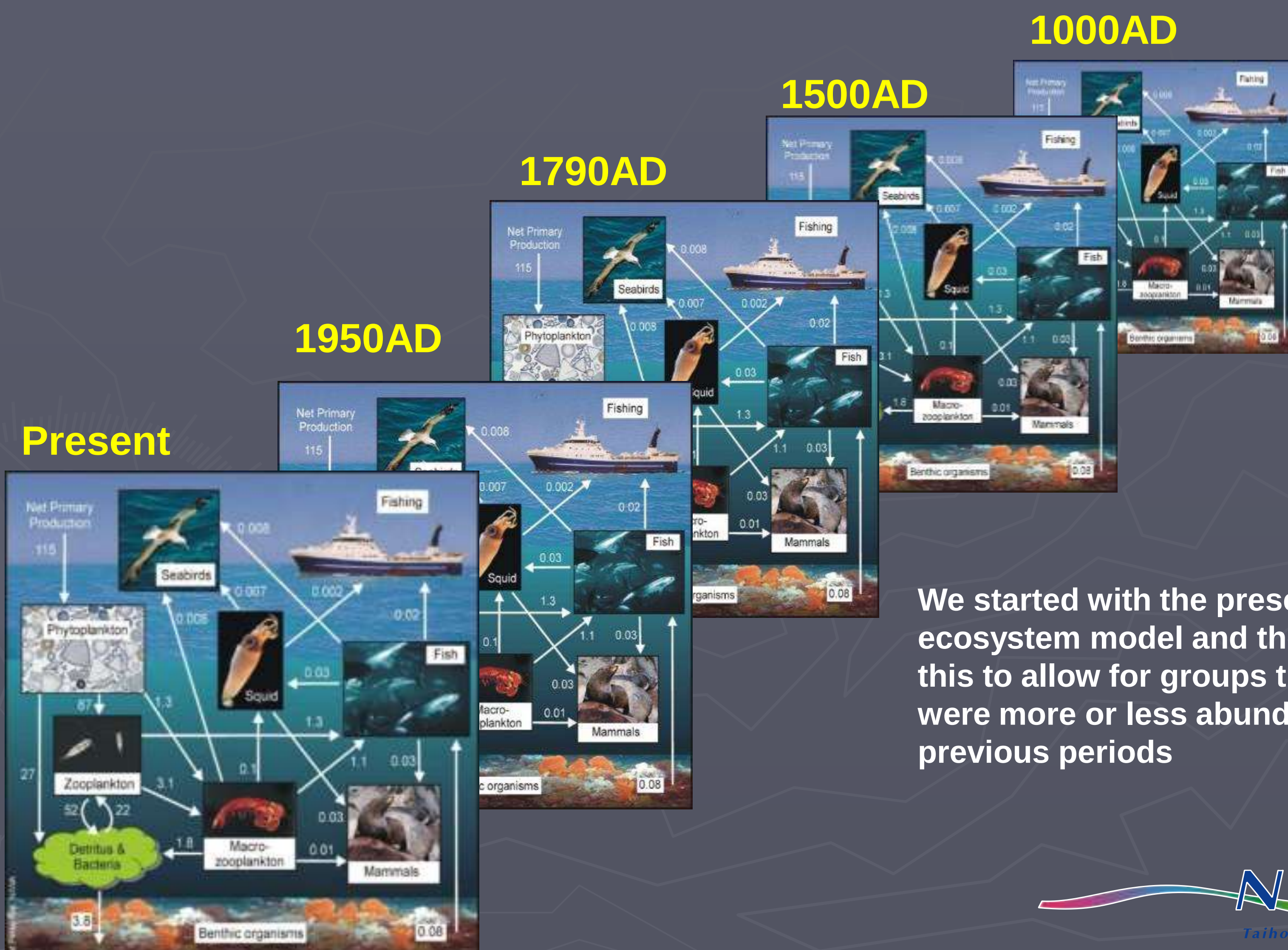
Other species are unlikely to recover

- NZ sea lion
- Females return to natal beaches to breed
- New evidence of Jon Waters and students at University of Otago from ancient DNA derived from midden specimens suggests that the population that once lived along northern coasts is genetically distinct (perhaps to a species level) from the NZ sea lion around southern coasts

Models of present and past versions of Hauraki Gulf marine ecosystem



We started with the present shelf ecosystem model and then adjusted this to allow for groups that we know were more or less abundant in previous periods

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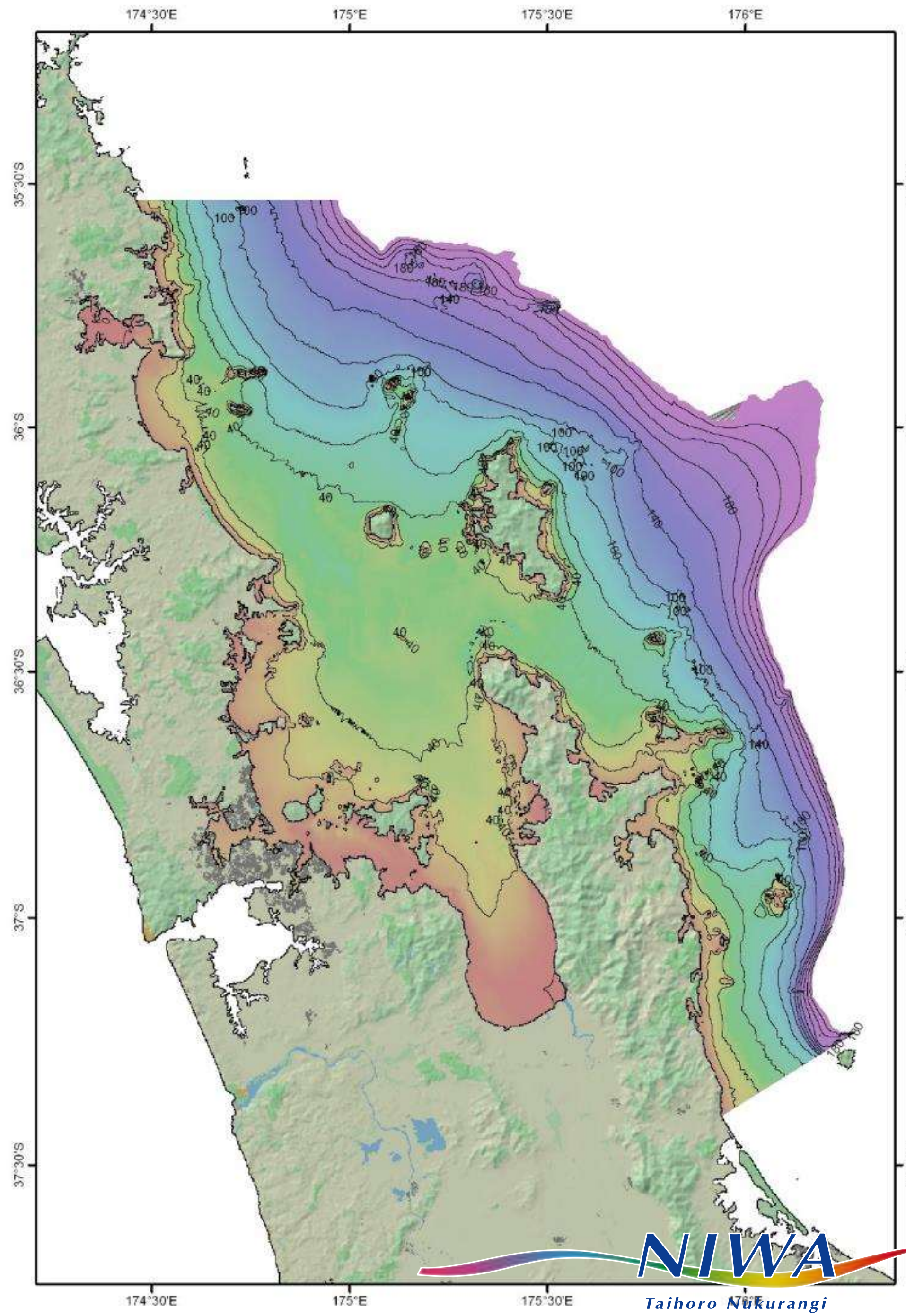
Present-day model: what species are present?



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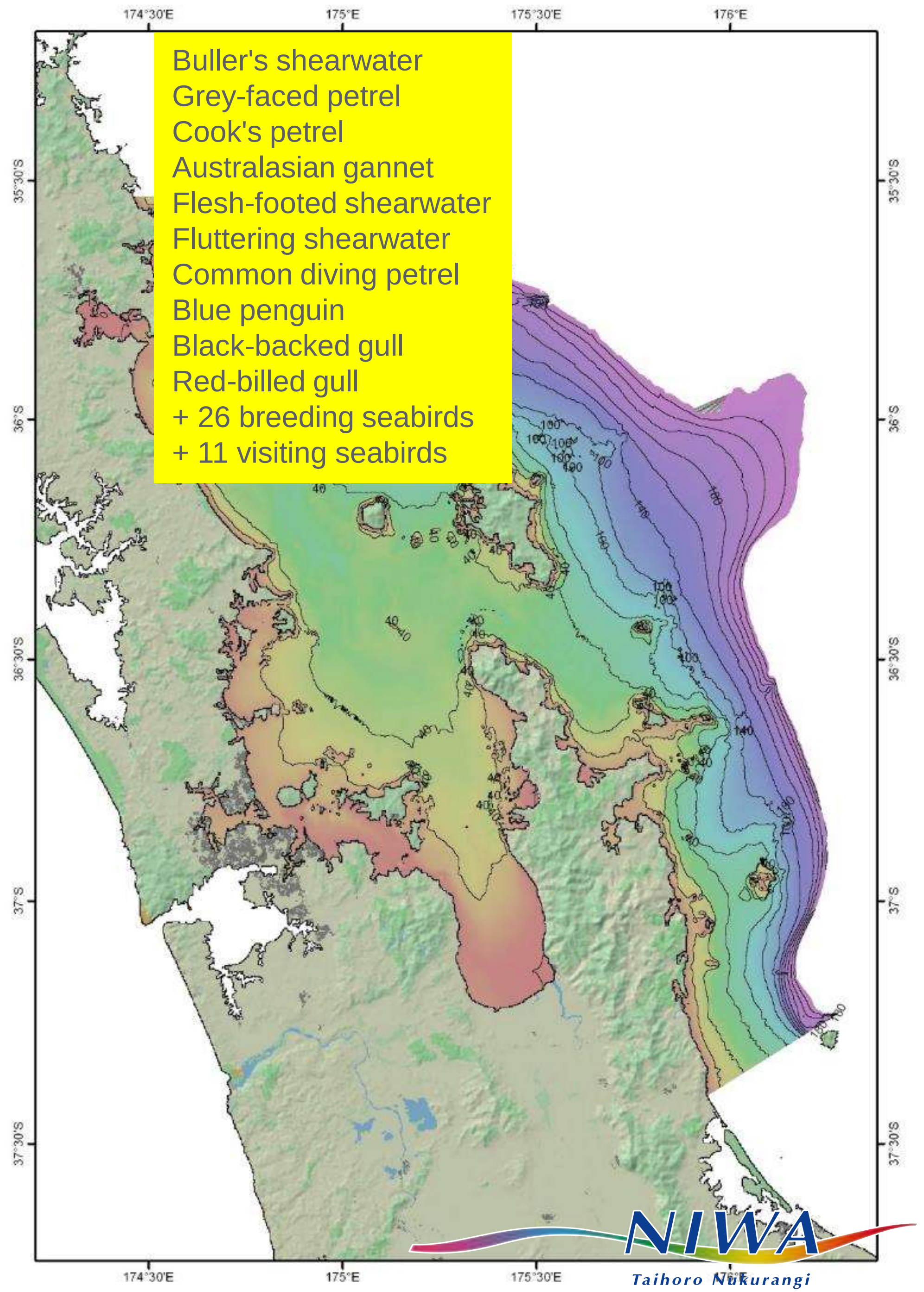
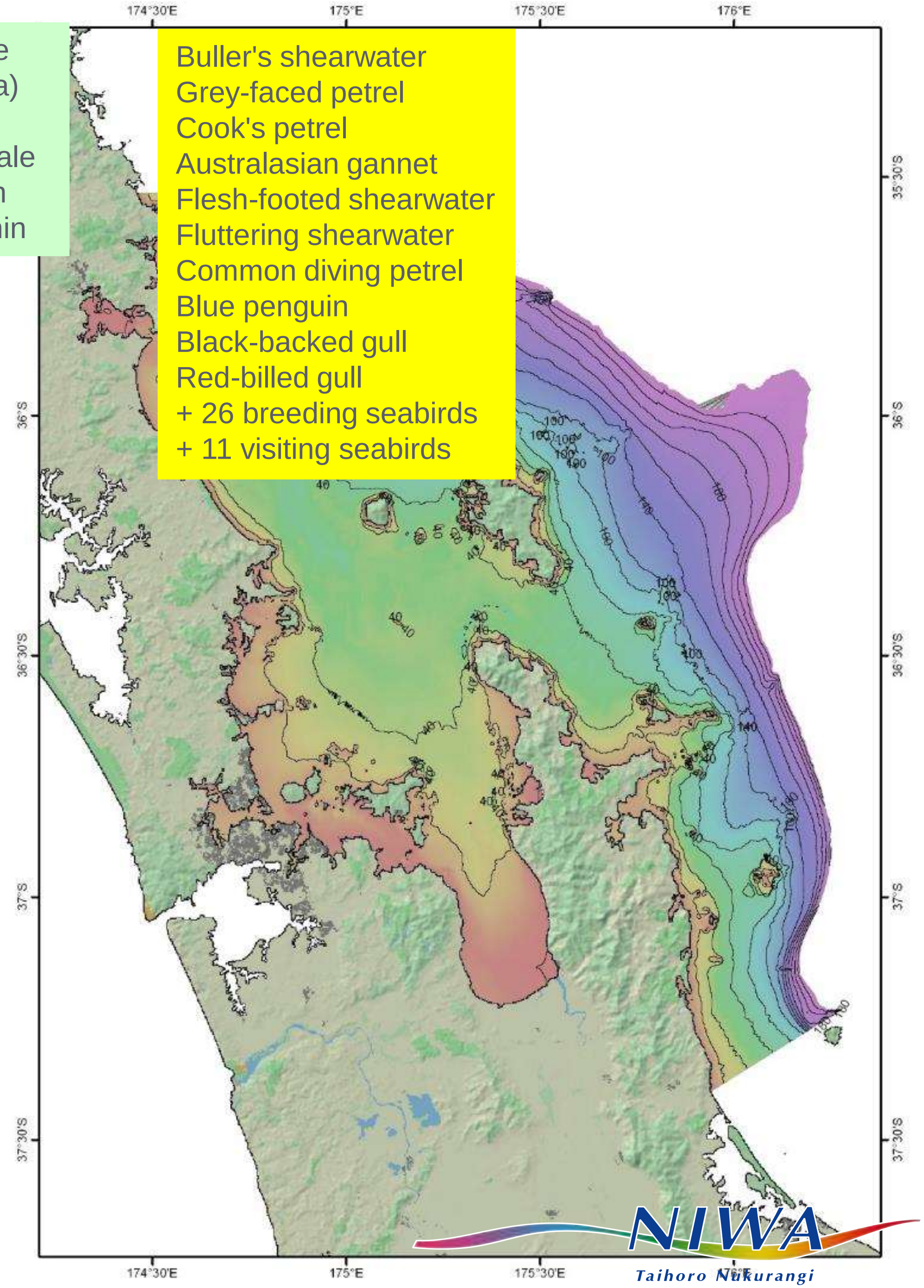
Species present…



Species present…

- Humpback whale
- Killer whale (orca)
- Bryde's whale
- Long fin pilot whale
- Common dolphin
- Bottlenose dolphin

- Buller's shearwater
- Grey-faced petrel
- Cook's petrel
- Australasian gannet
- Flesh-footed shearwater
- Fluttering shearwater
- Common diving petrel
- Blue penguin
- Black-backed gull
- Red-billed gull
- + 26 breeding seabirds
- + 11 visiting seabirds



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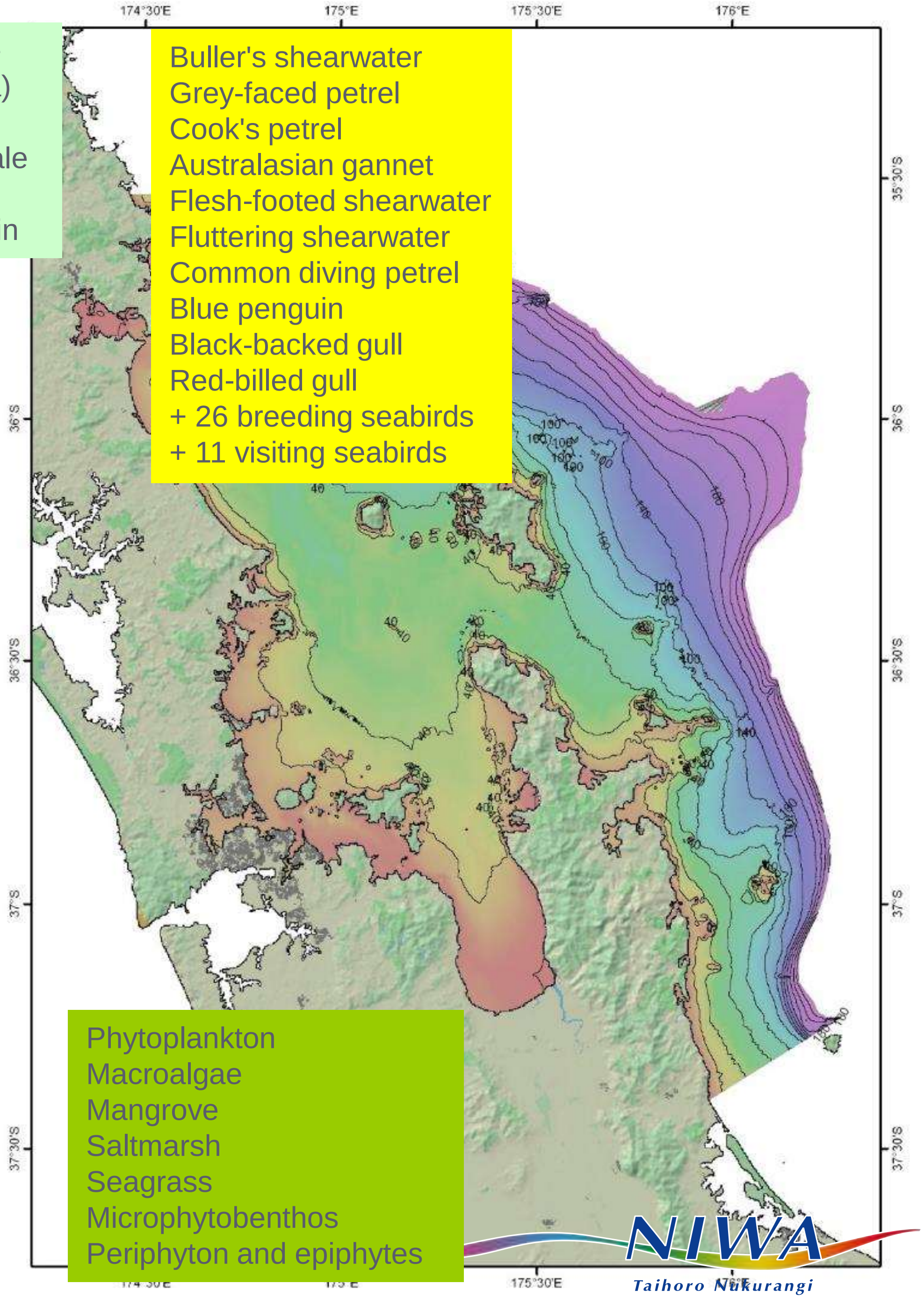

Phytoplankton
Macroalgae
Mangrove
Saltmarsh
Seagrass
Microphytobenthos
Periphyton and epiphytes

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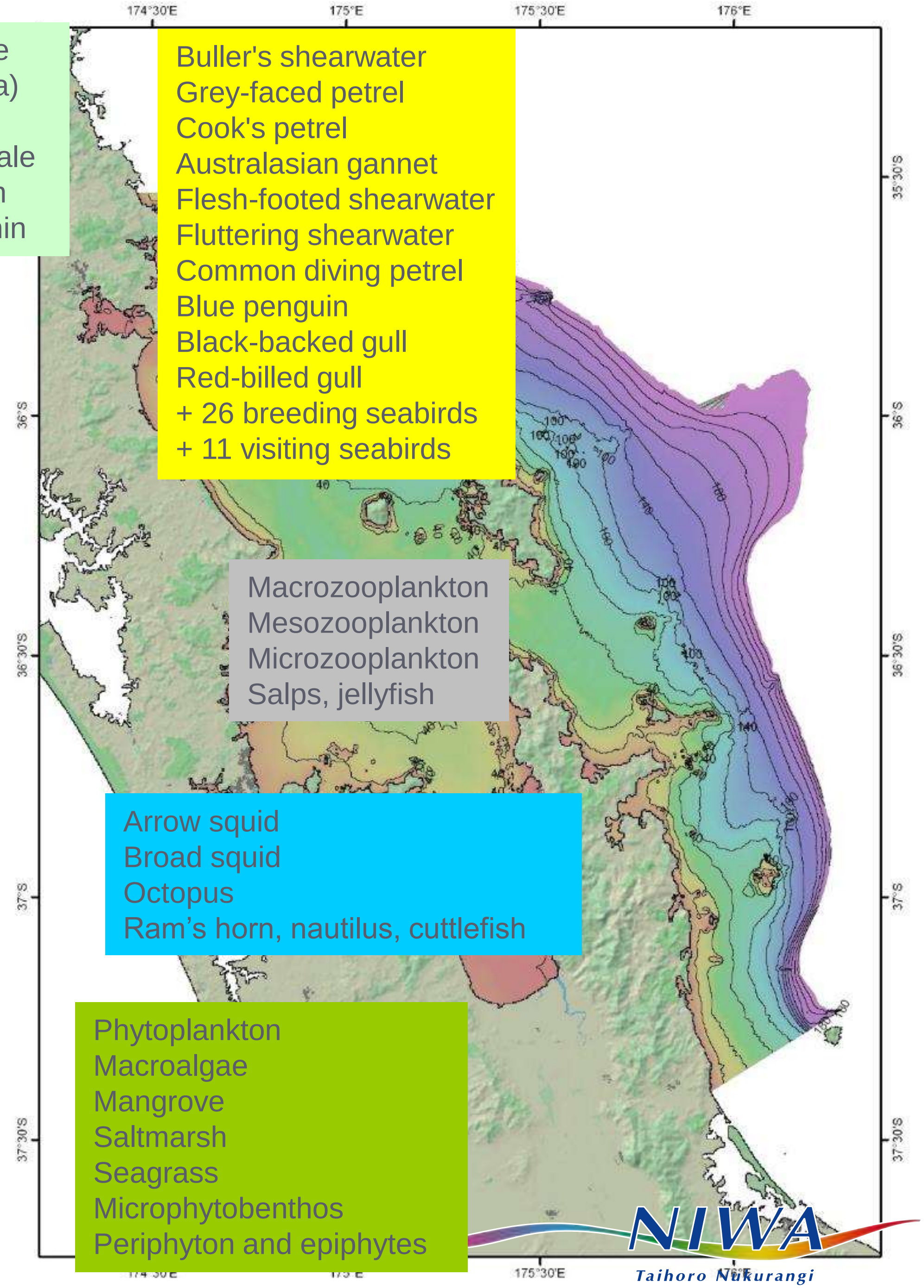

Buller's shearwater
Grey-faced petrel
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Macrozooplankton
Mesozooplankton
Microzooplankton
Salps, jellyfish

Arrow squid
Broad squid
Octopus
Ram's horn, nautilus, cuttlefish

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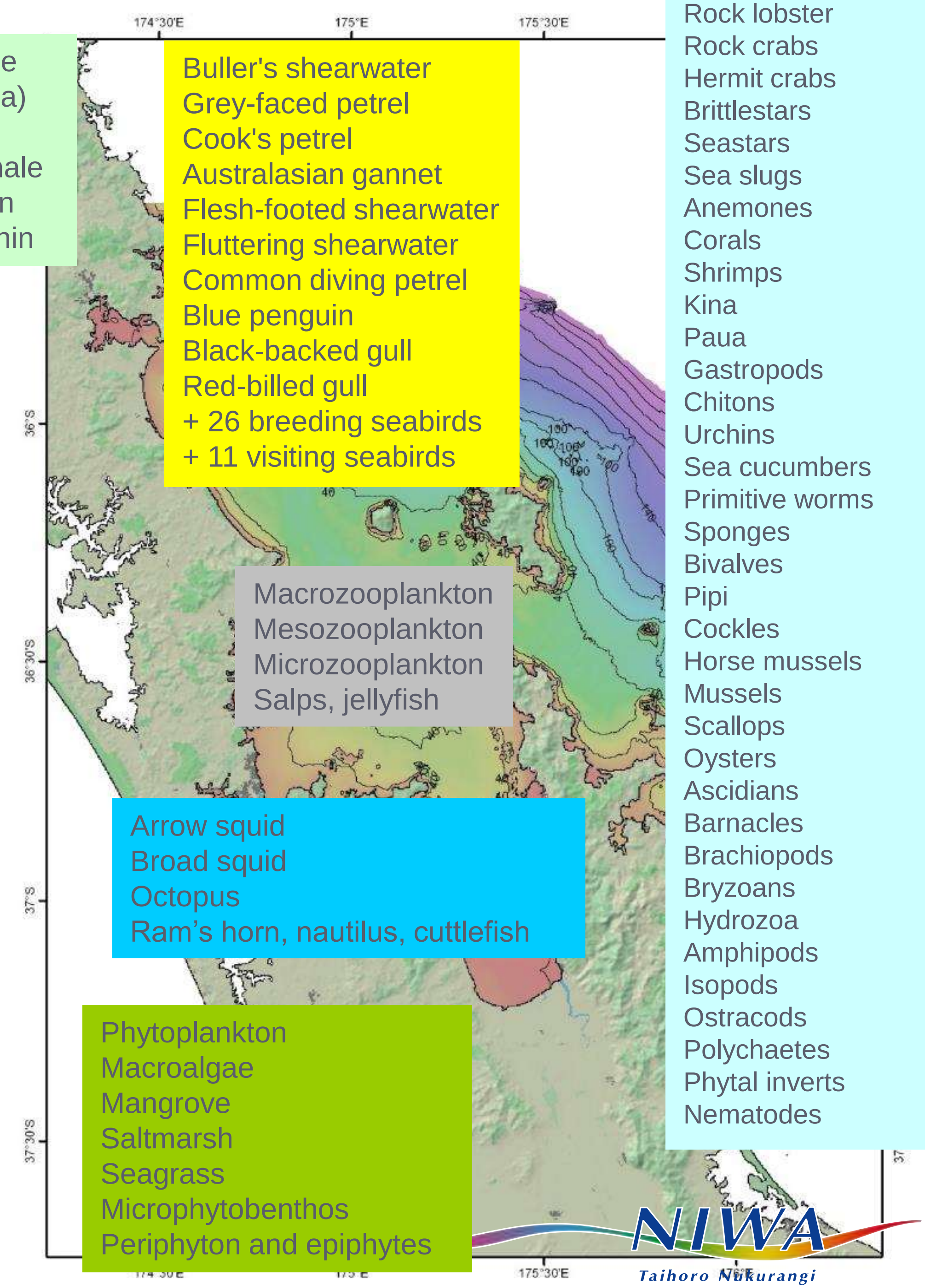

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Rock lobster
Rock crabs
Hermit crabs
Brittlestars
Seastars
Sea slugs
Anemones
Corals
Shrimps
Kina
Paua
Gastropods
Chitons
Urchins
Sea cucumbers
Primitive worms
Sponges
Bivalves
Pipi
Cockles
Horse mussels
Mussels
Scallops
Oysters
Ascidians
Barnacles
Brachiopods
Bryzoans
Hydrozoa
Amphipods
Isopods
Ostracods
Polychaetes
Phytal inverts
Nematodes

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Species present…

Ahuru
Anchovy
Banded triplefin
Banded wrasse
Barracouta
Bigeye
Black angelfish
Blue cod
Blue (English) mackerel
Blue maomao
Blue moki
Blue-dot triplefin
Blue-eyed triplefin
Bluefish
Bronze whaler
Butterfish
Butterfly perch
Carpet shark
Clown toado
Common roughy
Common triplefin
Common warehou
Conger eel
Crested blenny
Demoiselle
Dory (other)
Dwarf scorpionfish
Eagle ray
Elephant fish
Estuarine triplefin
Flatfish
Frostfish
Gemfish
Giant boarfish
Giant stargazer
Goatfish
Gobies
Golden snapper
Grey mullet
Hagfish
Half-banded perch
Hammerhead shark
Hapuku & bass
Hiwihiwi

Jack mackerels
Japanese gurnard
John dory
Kahawai
Kingfish
Koheru
Leatherjacket
Long-finned boarfish
Mado
Marblefish
Moonfish
Moray eels (other)
Mottled triplefin
Northern bastard cod
Northern scorpionfish
Oblique triplefin
Opalfish
Orange clingfish
Orange wrasse
Parore
Pilchard
Pink maomao
Piper, garfish
Porae
Porcupinefish
Ray's bream
Red cod
Red gurnard
Red moki
Red pigfish
Redbait
Red-banded perch
Rig
Robust triplefin
Rock cod
Rough & smooth skate

Sandager's wrasse
Scaly-headed triplefin
Scarlet wrasse
School shark
Sea perch
Sevengill shark
Shark (other)
Silver drummer
Silver warehou
Skipjack
Slender roughy
Snapper
Southern bastard cod
Spectacled triplefin
Spiny dogfish
Spotted black grouper
Spotty
Stargazer (other)
Stingray
Sweep
Swordfish
Tarakihi
Trevally
Trumpeter
Tuna (other)
Twister
Urchin clingfish
Variable triplefin
Worm eel
Wrasse (other)
Yaldwyn's triplefin
Yellow moray
Yellow-black triplefin
Yellow-eyed mullet

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Bivalves
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Cockles
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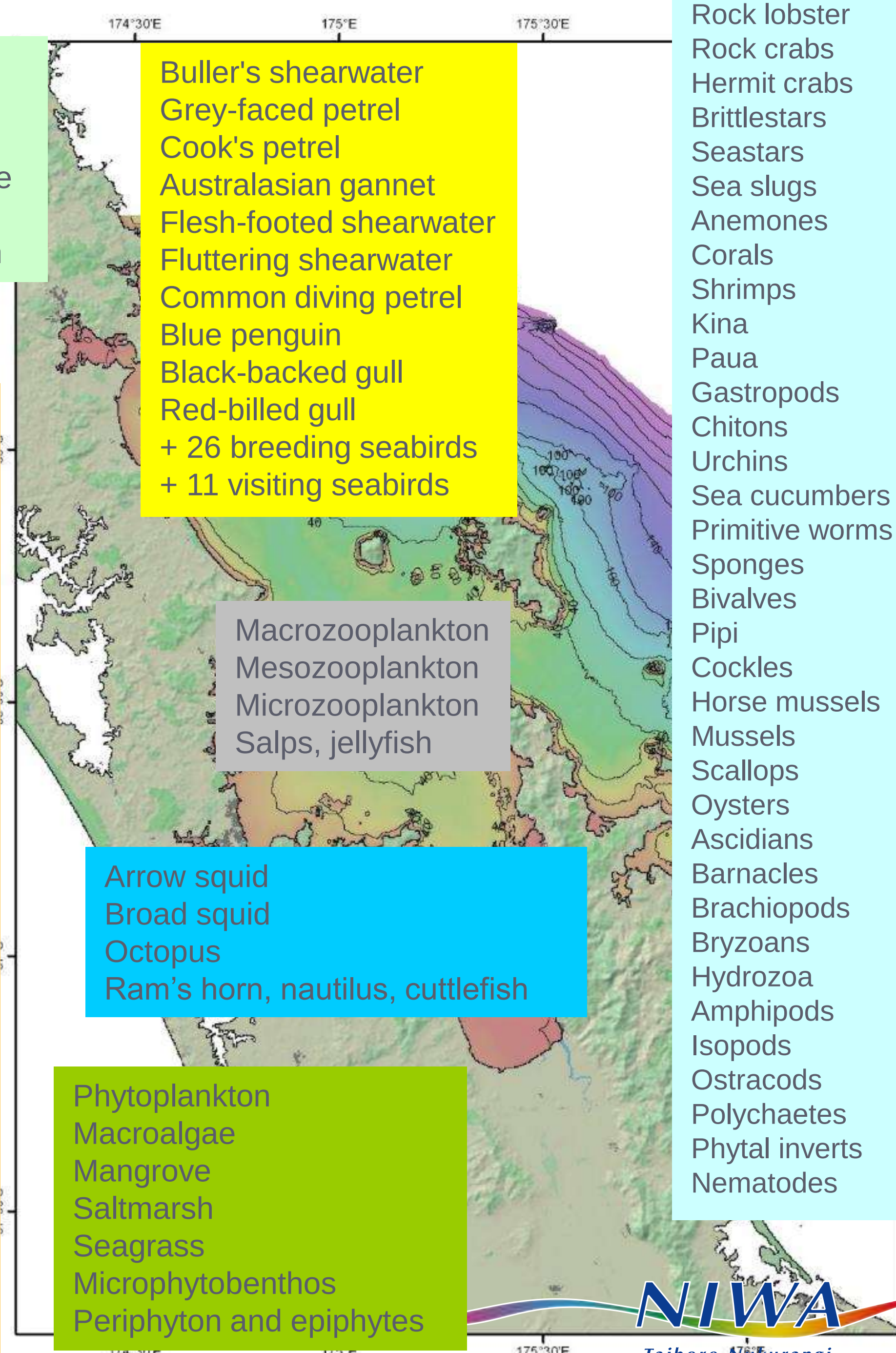
Nematodes



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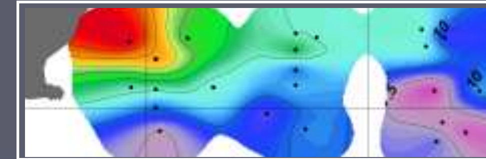
Building a foodweb model

Population models

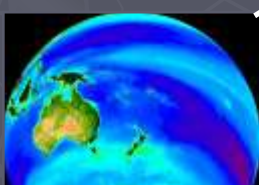
Literature

Stomach analysis



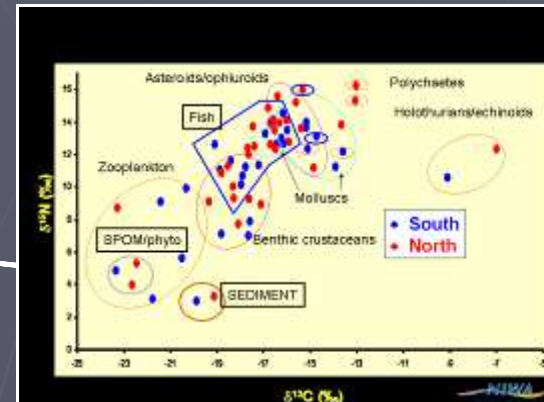
Biogeography

Voyages / surveys

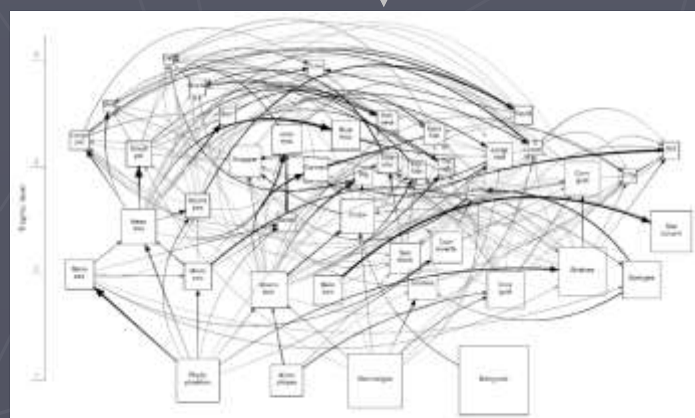


Remote sensing

Mass-balance model



Stable isotope / tracers



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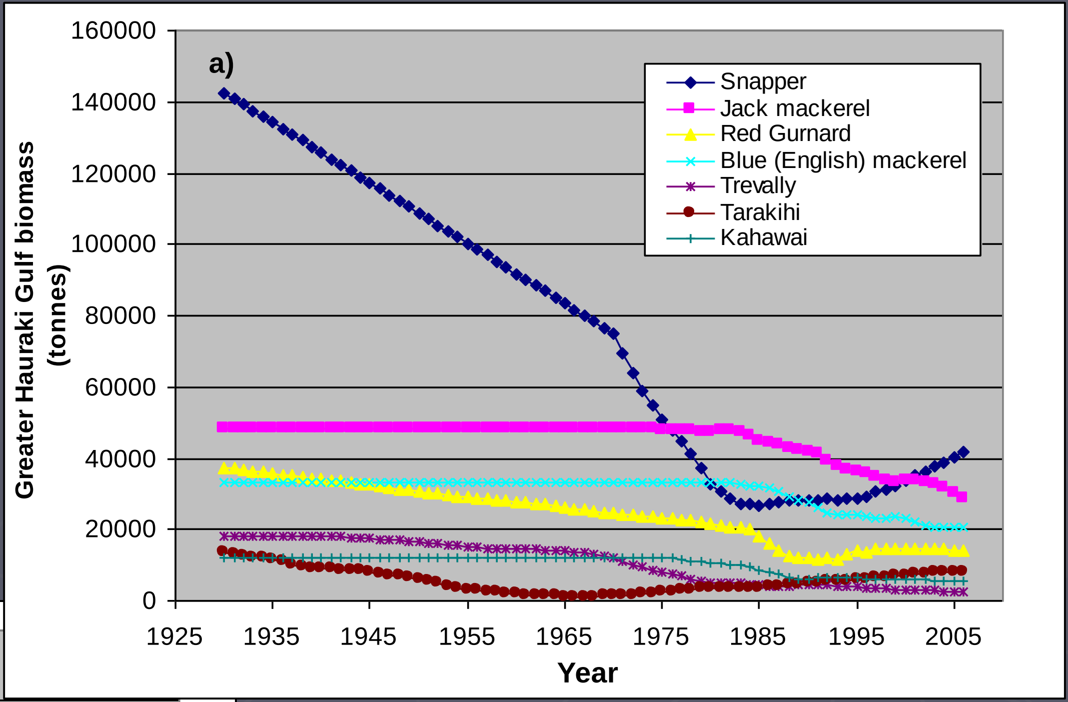
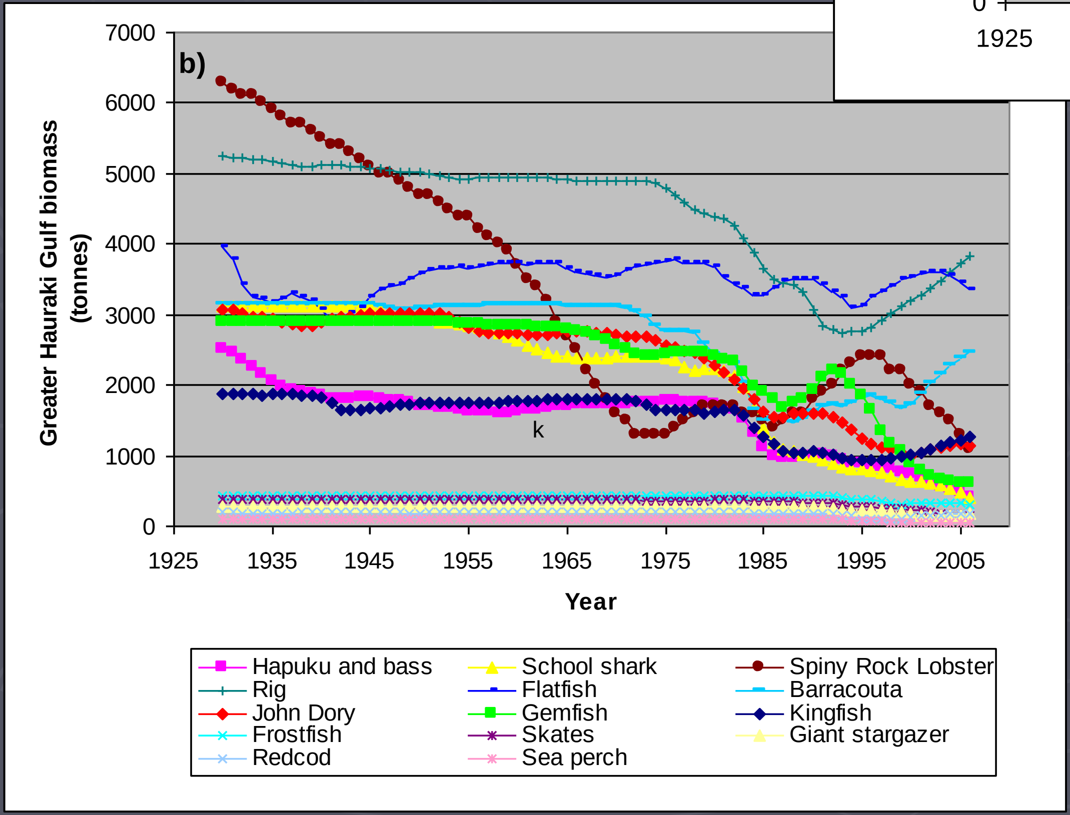
Historical models were driven by biomass trajectories of harvested species





Especially large biomass decrease in snapper and rock lobsters

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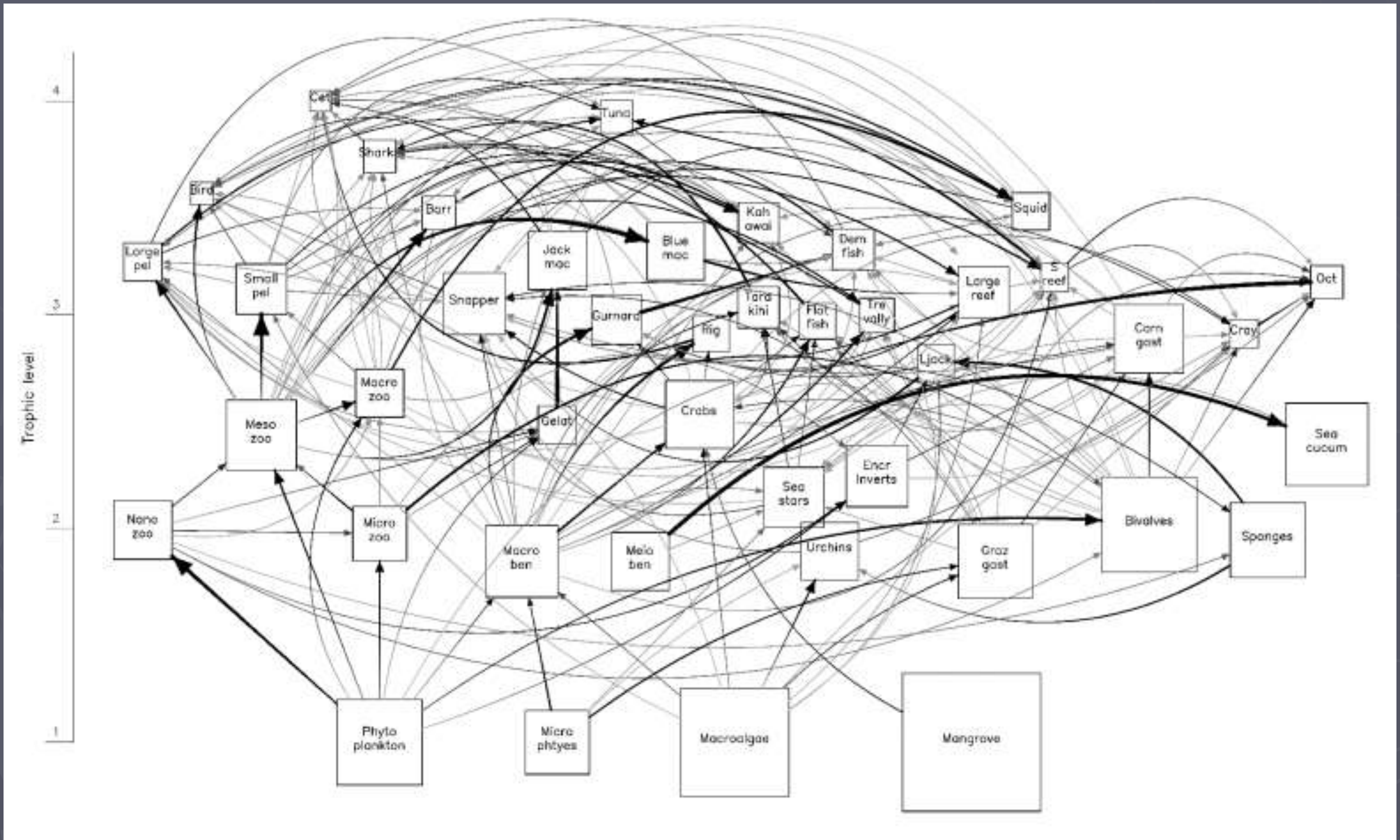
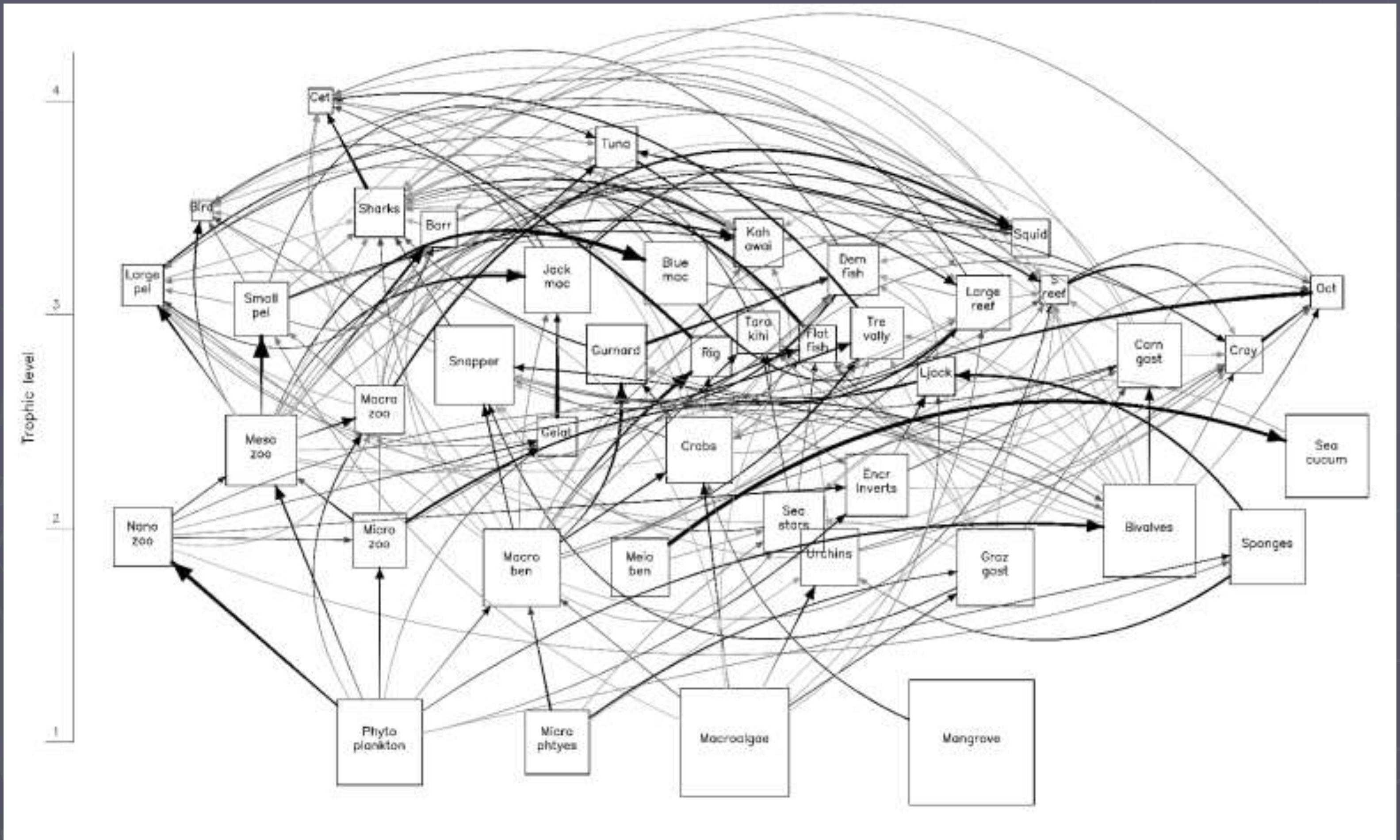
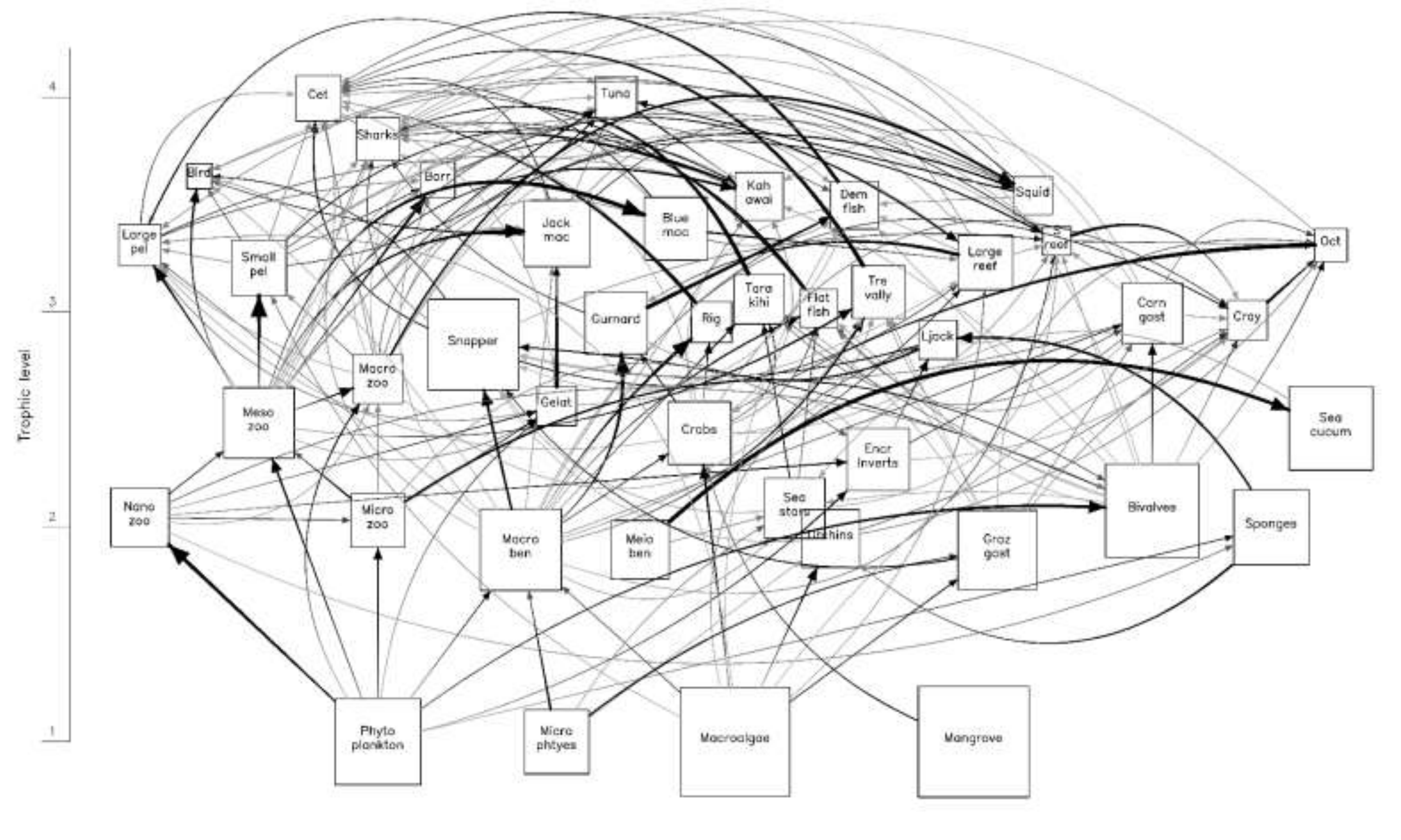
Present Day ~ 2006



1950 AD


Trophic level
4
3
2
1
Cet
Tuna
Bird
Sharks
Barr
Kah awai
Squid
Large pel
Small pel
Jack mac
Blue mac
Dem fish
Large reef
S reef
Oct
Snapper
Gurnard
Rig
Tara kihi
Flat fish
Tre vally
Corn gast
Cray
Ljack
Macro zoo
Gelat
Meso zoo
Crabs
Sea cucum
Encr Inverts
Nano zoo
Micro zoo
Macro ben
Meio ben
Sea stars
Urchins
Graz gast
Bivalves
Sponges
Phyto plankton
Micro phtyes
Macroalgae
Mangrove

1790 AD



Trophic level
4
3
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Cet
Tuna
Sharks
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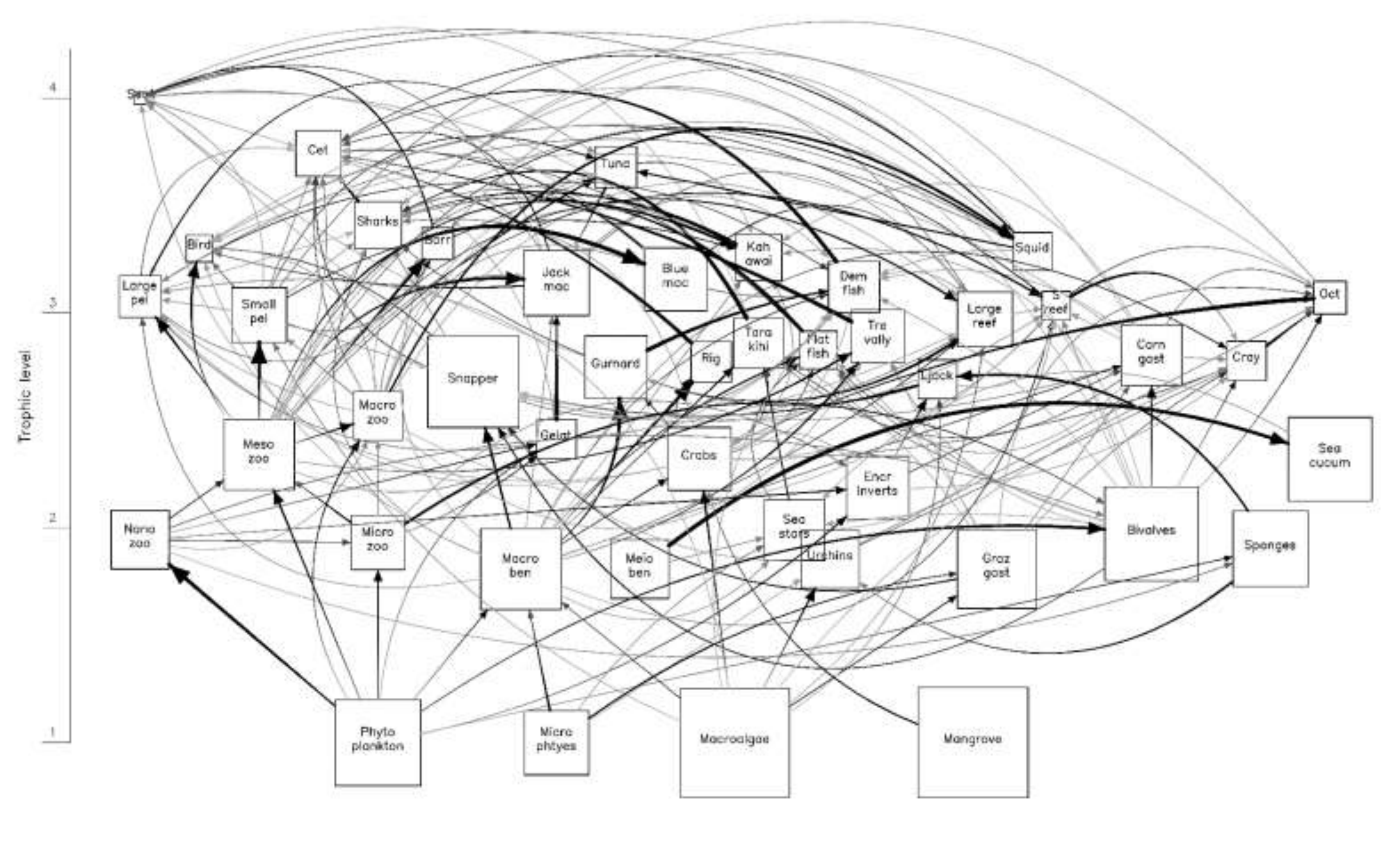
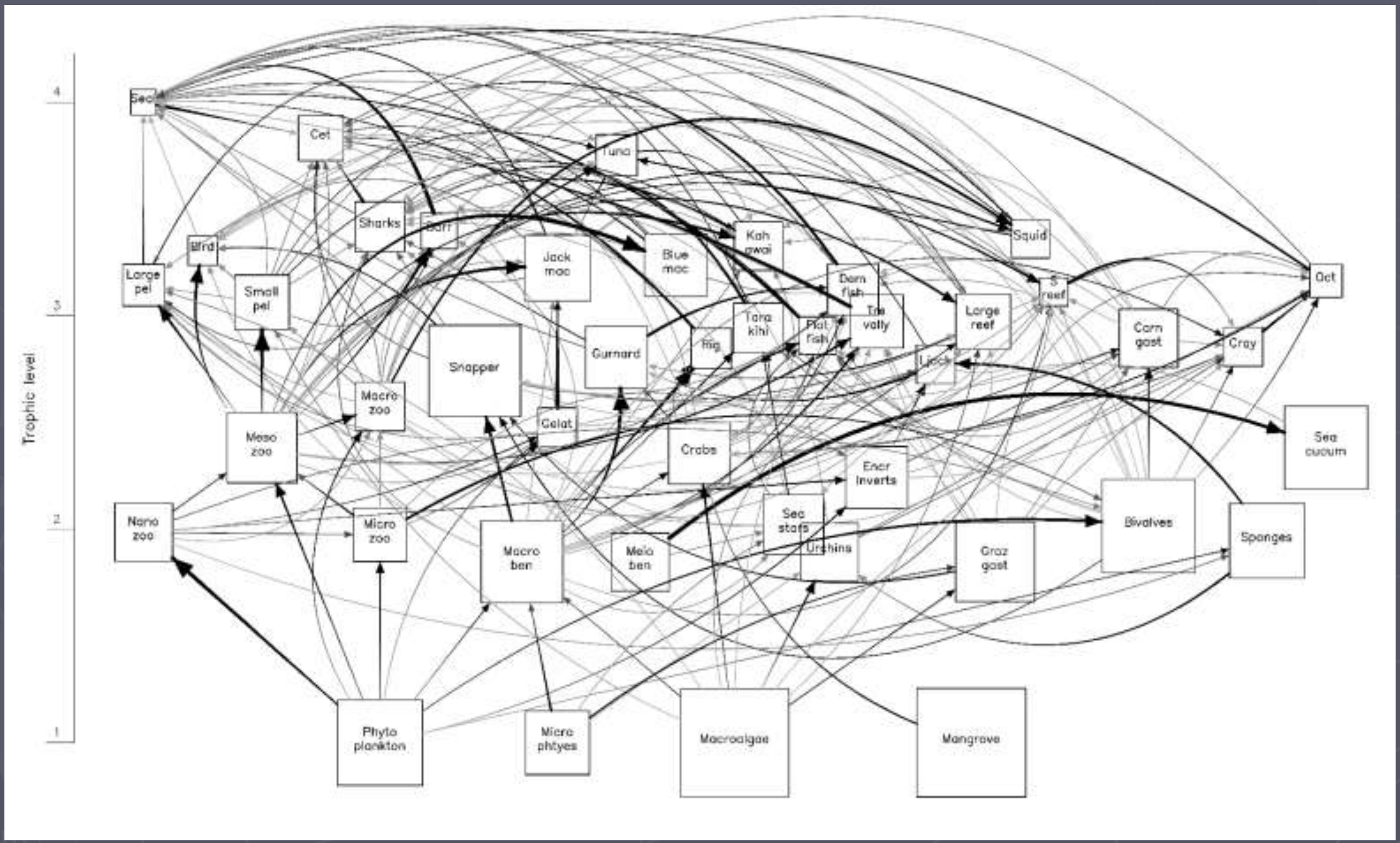
Kah awai
Dem fish
Squid
Large pel
Small pel
Jack mac
Blue mac
Large reef
S reef
Oct
Tara kihi
Flat fish
Tre vally
Gurnard
Rig
Corn gast
Cray
Snapper
Ljack
Macro zoo
Meso zoo
Gelat
Crabs
Sea cucum
Encr Inverts
Nano zoo
Micro zoo
Macro ben
Meio ben
Sea stars
Urchins
Graz gast
Bivalves
Sponges
Phyto plankton
Micro phtyes
Macroalgae
Mangrove

1500 AD



Trophic level
4
3
2
1
Cet
Tuna
Sharks
Bird
Barr
Large pel
Small pel
Jack mac
Blue mac
Kah awai
Squid
Dem fish
Large reef
S reef
Oct
Tara kihi
Flat fish
Tre vally
Rig
Gurnard
Snapper
Macro zoo
Meso zoo
Gelat
Crabs
Ljack
Corn gast
Cray
Sea cucum
Encr inverts
Sea stars
Urchins
Bivalves
Sponges
Nano zoo
Micro zoo
Macro ben
Meio ben
Graz gast
Phyto plankton
Micro phtyes
Macroalgae
Mangrove

1000 AD



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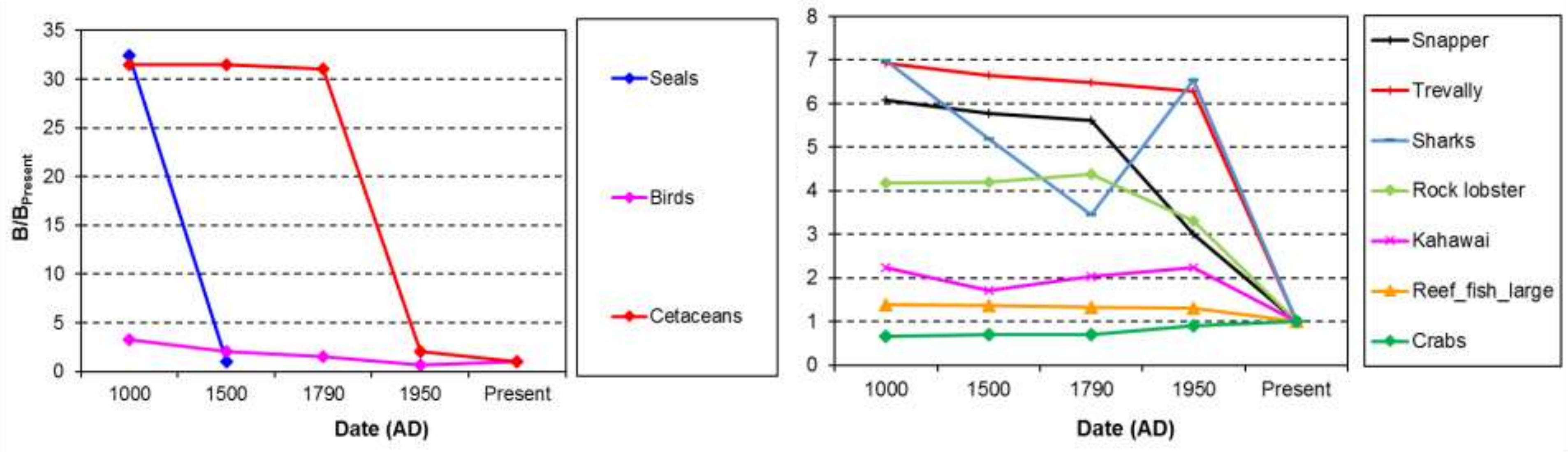
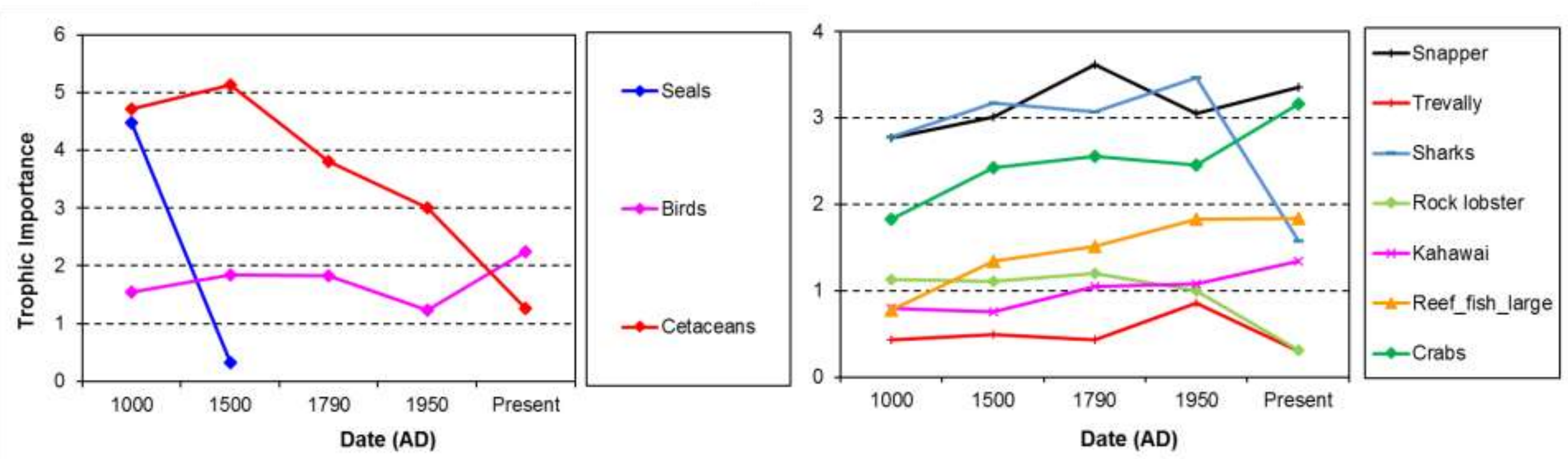
Mangrove

Changes through time: Biomass



… and trophic importance (indication of role in the system)



Patterns of change in trophic importance in the models

1. Before humans arrived, cetaceans and seals/sea-lions were the most trophically important groups in the region. Cetaceans are now 17th/46 Seals/sea- lions were extirpated from the ecosystem before 1790 AD.

2. Rock lobster was the 3rd most trophically important benthic invertebrate group in the region before human arrival. Rock lobster are now the least important.

3. Sharks were the most trophically important fish in the region between 1000 and 1950 AD. Between 1950 AD and the present day, the trophic importance of sharks decreased and now snapper are the most trophically important fish in the model.

4. The trophic importance of birds increased from 22nd (1950 AD) to 8th (present-day). Even though they had much higher abundances in 1000 AD and 1500 AD than in the present-day, birds did not have as high a trophic importance then as they do now.

5. Trophic levels of almost all organisms have increased from 1000 AD to the present. Because there were substantially more consumers in the past most predators were likely to feed at a slightly lower trophic level.

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Summary and Conclusions

- Humans arrived in NZ with established fishing technologies
- The impact of small human populations, first Maori then European, on vulnerable species was rapid and dramatic
- Some of the declines occurred before the statistical era and are rather opaque to us today but need to be acknowledged
- Other species such as snapper, despite a long period of exploitation, demonstrate considerable resilience
- There have been some changes in the structure of the Hauraki Gulf ecosystem during human occupation with some components missing and others greatly reduced in biomass
- In the models, marine mammals, sharks and rock lobster have declined in trophic importance, while birds, some fish (large reef fish, kahawai, snapper), and crabs have increased in trophic importance
- Some species are recovering and extending back into areas not considered in modern times to be suitable habitat – e.g. NZ fur seals
- History counts – for example we are still living with the ecological consequences of early Māori seal hunting and European whaling, as well as late 19th and early 20th century exploitation and habitat change and loss.
- NZ can tell this story probably better than anywhere

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Taihoro Nukurangi