the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI

FUTURE MARINE RESOURCE USE

Emerging Issues

Our vast oceans
New Zealand's Exclusive Economic Zone and Extended Continental Shelf cover an area of more than six million square kilometres, more than twenty times our land area. The waters of the Realm of New Zealand range from the tropical waters around Tokelau to the ice shelf of the Ross Sea, including ecosystems from ten to eighty degrees South, and are similar in size to the ocean area claimed by the United Kingdom. Half of this ocean is deeper than two thousand metres and the majority of the deep seabed is unexplored.

These regions represent a vast store of potential wealth, both in economic terms and in ways that are harder to quantify but underpin human wellbeing. Our ability to access these resources continues to increase, as does our capacity to cause damage. Growing concerns over global food security, energy costs, and a growing world population are adding pressure for access and highlighting the need for effectively managing the impacts of that access. There are differing views regarding ownership of these resources and clarifying these will be a crucial part of their responsible use.

This paper reviews our stocks of living and non-living marine resources and the knowledge needed to benefit from them economically. For each resource, there is the potential for increased flows of benefits from those stocks, but knowledge and careful management is required to ensure that those benefits are sustained over the long term, not just the short term. Much of that knowledge focuses on the rates at which resources respond to existing stresses such as overfishing, increased rates of sedimentation and nutrient input from on-land activities, along with growing and cumulative stresses such as warming, acidification, and underwater noise pollution. This paper does not address governance issues, these are well-covered by the recent *Ocean Governance* report.[2]

Ecosystem services from the marine environment and our little-studied but unique and rich biodiversity
In 2008 under the UN Convention on the Law of the Sea, New Zealand's sovereign rights extend beyond the Exclusive Economic Zone (EEZ) to the Extended Continental Shelf (ECS), adding an area six times the land area of New Zealand. New Zealand has constitutional obligations regarding the EEZs of the Cook Islands, Niue, and Tokelau and also directly administers the Ross

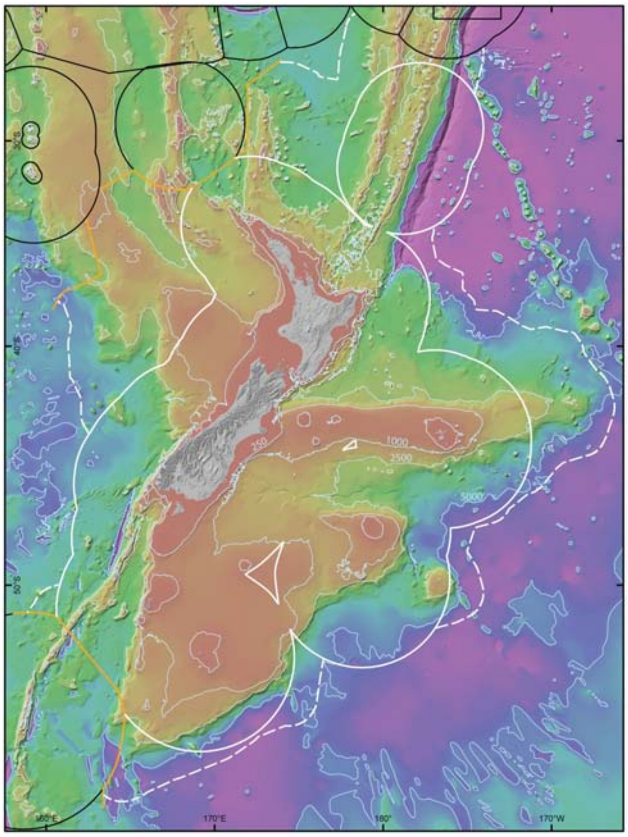

Figure 1: New Zealand's Exclusive Economic Zone. The white line shows the EEZ boundary, the dashed line shows the legal continental shelf, and black lines show the EEZs of Australia and island states.[1]

Dependency in Antarctica. Together, these make up the waters of the Realm of New Zealand, as described in Table 1.

New Zealand's marine responsibilities span a wide range of different waters, from sub-tropical to ice shelves, and thus we have responsibility for an equally large range of ecosystems. The corresponding biodiversity is poorly explored but there are strong suggestions that New Zealand marine biodiversity is more complex than that of equivalent areas in, for instance, the European marine regions. The reason for this complexity is not known but may be a product of tectonic history, position relative to major currents, diversity of habitats, and reach across many latitudes.[3]

Region	Area (km^2)
Land area[4]	268,000
NZ Exclusive Economic Zone[5]	4,300,000
Extended Continental Shelf[6]	1,700,000
Cook Islands, Niue, & Tokelau EEZs [7]	2,600,000
Ross Dependency[8]	410,000

Table 1: The size of the Exclusive Economic Zone and other ocean areas where New Zealand has responsibilities. The Extended Continental Shelf rights only cover the seabed.

Marine resources provide a wide range of different services to humanity (as described in Table 2), creating different kinds of value to varied user groups. Biological resources may be directly involved in the ecosystem functions that underpin ecosystem services, while all resource extraction has the potential to impact on some ecosystem services. Using these resources to generate solely short-term financial gain is often a false economy and has led to large economic losses on top of social and environmental losses. Losses through poor management, depletion of stocks and excessive fishing effort have been estimated by the World Bank at US$50 billion per year for global fisheries.[9]

One route to directly realising financial value from New Zealand's biodiversity is through biodiscovery. The unique flora and fauna of New Zealand are a source of a wide range of novel and biologically active chemicals, some of which may have commercial value as pharmaceuticals. Protective, potent, and biologically targeted chemicals are used by, for instance, soft-bodied species of immobile sponges that have few other defences against predators. New Zealand's high degree of marine biodiversity translates into a high degree of chemical diversity available to researchers.[10] For example, New Zealand waters contain nine hundred species of *byrozoans* (lace corals), of which two-thirds are endemic. Biochemicals from these animals (bryostatins) are currently under investigation as antitumour agents for cancer therapy. Resolving the Wai 262 Treaty claim over flora and fauna and developing a clearer stance from New Zealand authorities on customary use rights, title, access rights and benefit sharing will be useful in encouraging and managing biodiscovery in New Zealand waters.

Well-managed but finite wild fisheries

Globally, 80% of fish stocks are fully or over-exploited, with 25% of monitored stocks overexploited or depleted.[11] Wild fish stocks represent a stock of natural capital from which flows of nutrition and economic value can be gained. As with all stocks, overuse reduces future flows and future income. Assessment of fish stocks is difficult due to limits on monitoring and prediction, species diversity, natural variability, and (in some cases) migratory lifestyles. However, of the 636 managed stocks in New Zealand waters, there is sufficient information to assess 164 stocks, representing 66% of total catch by weight and value. In 2011, over 90% of these stocks were defined as "not overfished".[12]

New Zealand's territorial waters and wild fish stocks are largely isolated, such that our resources are largely uncontested by other nations. Strong and effective institutions are recognised as necessary to ensure sustainable use and long-term survival of the resource. Historically, the Chatham Island rock lobster fishery provides one of many textbook examples of a poorly regulated New Zealand fishery, with the stock commercially destroyed in the seven years from 1966. Over a longer term, snapper biomass has declined by more than 90% over the last seven hundred years; right whales in NZ waters have declined by possibly 99% over the last two hundred years.[13]

Many New Zealand fish stocks (particularly inshore species) had been depressed to low levels before the Quota Management System (QMS) was introduced in 1986. The QMS is generally held responsible for the recovery of the NZ fishing industry.[14] After more than two decades of relatively effective fisheries management, many of the inshore stocks have recovered. Some, like hoki or southern blue whiting, have shown major variations in abundance (probably due to a combination of environmental and fishing factors) that have been well managed to allow for recovery to target levels. A Harvest Strategy Standard ensures that key stocks are managed appropriately when they fall below particular limits. After twenty-five years under the QMS, New Zealand fisheries are considered relatively healthy by global standards.

Although the fisheries are well-managed, there is potential to increase the benefit we derive from them through increased value-add by improved processing and marketing of the existing catch, temporary reductions in fishing pressure to allow stocks to recover, and ecosystems-based fisheries management.

Increasing fish stocks through deliberate underfishing can "increase productivity, profitability, and net economic benefits… and increase sustainable yields and lower fishing costs".[9] The great depletion of marine biomass over the past two centuries suggests that huge benefits may arise from a recovery towards that virgin state. However, it is difficult to quantify the return on investment for underfishing (in terms of the current cost of reducing harvests in the short-term), limiting the impetus for such an investment.

The interconnectedness of different fish stocks is recognised to a large extent by incorporating 636 stocks into the QMS. However, evidence of the connections with and impacts on non-fish by-catch species is mounting, leading to a push to include management measures based on the overall health of ecosystems. Such measures will require an improved understanding of the effects of fishing and other drivers upon those ecosystems. The ultimate goal would be to match the degree of fishing impact with an acceptable level of impact upon valued species, habitats, and ecosystems using a management system that accounts for uncertainties in knowledge about these components. At present, our knowledge of New Zealand marine ecosystems is far from that ideal and rarely sufficient to allow even mapping of biodiversity hotspots to support focused protection of those hotspots.[3]

Ecosystem service class	Ecosystem service	Sub-class
Provisioning	Food	Ocean-caught fish Habitat for fish caught in freshwater (eel, whitebait) Future options for farming wild fish Future options for new aquaculture species
	Freshwater supply	Rain via the hydrological cycle
	Pharmaceuticals & chemicals	Bioprospecting for potential biologically active compounds
	Abiotic products	Oil and gas production Gravel, sand, and ironsands extraction Salt production Potential for other minerals
Regulating	Atmospheric regulation	Atmospheric oxygen production Main sink for carbon dioxide
	Climate regulation	Main sink for additional heat from warming
	Nutrient regulation	Storage & cycling of nutrients
	Sediment regulation	Physical & biological sediment capture & stabilisation
	Water purification	Capture, sequestration, & detoxification of pollutants
	Water regulation	Hydrological flow regulation (e.g. minimum flows)
Cultural	Conservation	Native biodiversity & habitat, endangered native species
	Education	Historical values, knowledge systems (e.g. navigation)
	Aesthetic & spiritual values	Natural character & beauty, life supporting capacity (mauri)
	Recreation	Boating, fishing, swimming, & surfing

Table 2: Ecosystem services provided by the oceans. Supporting services are implicit components of all other services.[15]

Oil and gas: potentially large but underexplored
New Zealand's oil and gas industry contributes around $2 billion per year to GDP, with that production coming from a very small segment of the continental shelf.[16] Estimates of the value of oil and gas in the remainder of the EEZ & ECS range widely, as only a small fraction of these regions have been thoroughly surveyed. Modern seismic data that could suggest the presence of a Maui-sized field is only available for 15% of the EEZ and, by world standards, few exploratory wells have been drilled (as shown in Figure 2).[17] The geological history of our marine environment derives mainly from international exploration through the International Ocean Drilling Programme (IODP) and its predecessor programmes. New Zealand's ongoing participation in IODP offers opportunities to further characterise the the resource potential of our oceans.

Geological evidence suggests that a great deal of petroleum is likely to be found in our oceans and this petroleum would be technically accessible. GNS Science estimates for half of the sedimentary basins in the EEZ suggest a range of 2-26 billion barrels of oil and 10-160 billion cubic feet of gas. For comparison, total Taranaki production of petroleum so far is approaching 2 billion barrels of oil equivalent. However, undiscovered petroleum is, by definition, difficult to quantify. The GNS/MED estimates are based on an incomplete seismic picture of New Zealand's complicated undersea geology and extrapolations based on the historical experience of size distributions of overseas fields, thus they need to be considered cautiously. Technical and economic factors add extra complexity to assessing this resource, with one study suggesting the future value of these reserves could vary by twenty-fold, depending upon future oil prices, the future tempo of exploration, and the outcomes of that exploration.[18]

The geological basins where petroleum may occur range from close offshore to several hundred kilometres out and in ocean depths of up to two kilometres. Those resources are likely to reside up to six kilometres below the seabed. The cost of accessing such resources continues to fall as technology improves and although New Zealand conditions pose no unusual technical difficulties, our harsh ocean conditions are challenging and the cost of mobilising drilling rigs here is high.

Gas hydrates: potentially larger than conventional gas
Gas hydrates are a potentially vast source of natural gas. First discovered in New Zealand waters only ten years ago, there appear to be large stocks along the continental shelf of the East Coast, Fiordland, Canterbury, and the Chatham Rise. There are also indications of their presence elsewhere. The East Coast resource may contain more than a hundred times the amount of gas that was present in the Maui field. However, gas hydrates are often very dispersed and no viable commercial extraction technique has been established, although research into producing gas from these resources is gathering pace around the world. However, a resource of this potential size justifies substantial further investigation.

Few areas have been thoroughly surveyed and more resources may be present along the continental shelf. Further assessment of potential resources will depend upon understanding how accumulations are formed, investigating reservoir and seal rocks, characterising specific reserves, and ongoing seismic surveying.

Minerals: present but little explored
The seabed of New Zealand's EEZ and ECS have deposits of ferromanganese nodules on the Campbell Plateau, phosphorite deposits on the Chatham Rise, and hydrothermal polymetallic sulfides along the active volcanic ridge of the Kermadec Arc and possibly throughout extinct volcanic arcs such as the Colville Ridge that extends from the Coromandel Peninsula and the Three Kings arc to the north-west of Northland. The polymetallic sulphides

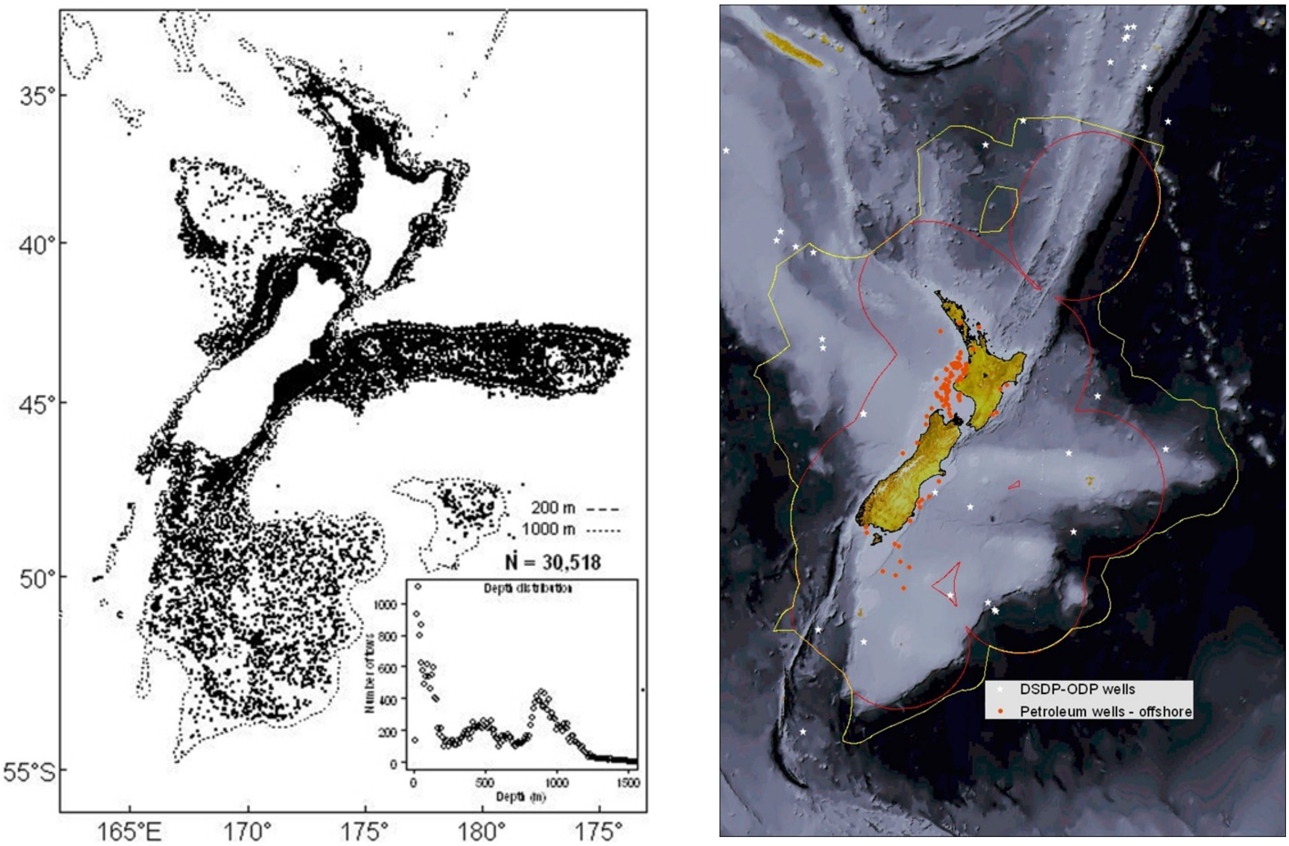

Figure 2: Left figure shows the locations of fisheries bottom trawls. The dotted line shows the 1000 metre contour and the lack of bottom sampling at greater depths.[3] Right figure shows geoscience & oil exploration wells drilled into the ocean floor[17] (right) for the New Zealand Exclusive Economic Zone (red line) and continental shelf (yellow line).

contain iron, manganese, gold, silver, copper, and zinc and are actively being formed at some submarine vents, raising the prospect of sustainable harvesting of a replenishing stock of minerals. Such hydrothermal vents, sometimes called “black smokers”, have only recently been discovered and research into both identifying high-grade ore deposits and understanding the ecological value of both active and inactive vent habitats is at an early stage.[17]

There is though, a great deal of uncertainty about the extent of many mineral deposits, how they are distributed, and how profitable they will be to extract. These are matched by uncertainty in the possible environmental impact of extraction, how to minimise impacts, and how socially acceptable any impact from mining might be.

This lack of critical knowledge is best illustrated by the management discussions regarding the ironsands resource off the Taranaki coast and the environmental impact of extraction. In contrast to our other marine mineral resources, the ironsands are better-understood, being close to shore and an extension of an on-shore resource. They contain billions of tonnes of ore. The seafloor ecosystem undergoes natural disturbances from storms and other events that redistribute sediment and smother habitats on the seafloor. If the size, reach, and frequency of these natural disturbances mimic those of proposed mining activity then the resilience of these habitats to natural disturbance may be a useable proxy for the resilience of these habitats to disturbance from mining. However, if the natural and anthropogenic disturbances act on the ecosystem in a cumulative fashion such simple comparisons would be poor proxies. In addition, the response of these habitats to the range of cumulative impacts (sediment and nutrient run-off from land-based activities; changes in temperature, acidity, and water flow due to climate change; disturbance from fishing; underwater noise; etc…) are equally poorly known, making it difficult to consider the impact from mining in the context of the other factors affecting these ecosystems. As the resilience of these habitats is poorly known (although under active investigation), management decisions about the impact of given levels of disturbance simply cannot be well-informed at present.

Plentiful marine energy awaiting use

The potential supply of electricity from wave and tidal currents exceeds New Zealand’s current electricity generation. Wave resources derive from swells generated in the storm-swept Southern Ocean and any south- or west-facing coast has waves which may be sufficient for power generation. Tidal current power generation is likely to be much more site-specific as power from tidal currents varies as the cube of the velocity, so any constriction (a channel or island off the mainland) can create a potentially attractive resource. Resource mapping indicates that Cook Strait has world class potential due to its large size and flows, followed by Foveaux Strait and some channels and harbours, such as Tory Channel and French Pass (both in Marlborough) and Kaipara Harbour.[20]

Other forms of ocean power (thermal or osmotic gradients, marine biomass for fuel, or offshore wind generation) are less suited to New Zealand conditions.[20]

With over two hundred wave and tidal current power generating technologies in development, convergence to a small number of basic designs, as happened with wind turbines, has still to occur. The price of electricity of prototype and pre-commercial machines is yet to become competitive but is falling rapidly as the industry goes through cycles of learning-by-doing, design refinement, siting optimisation, scaling up of machine size and economies of scale.

Marine generation is expected to become cost-competitive in the next two decades in the same way that wind generation has done this decade. However, forecasts of the timing of growth of the industry have proven too optimistic.

As with wind power, the generation potential from a given tidal current site depends crucially upon the range of flow speeds. The local shape of the sea-floor can accelerate local speeds, making accurate siting important for maximising power potential. Like wind power, the effect of extreme flows and the need for survival in storm conditions will affect the design of tidal power devices. However, unlike wind power, peak flows are less of a constraint on undersea turbine design and maintenance. Instead, turbulence at the scale of the turbine is a critical design factor and may determine reliability and economic viability. For New Zealand sites, this turbulence is not well characterised; on-site measurement is expensive and thus rare.[21]

Marine power could offer electricity with the promise of very limited environmental impacts and there is likely to be little impact upon human activities. Potential ecological impacts need to be understood; topics of ongoing investigation are the local impact of reduced tidal flows and the possible effects upon biota, including fish spawning and marine mammals. Underwater noise may also be a concern. Tidal power extraction slows currents and reduces tidal flows. These effects may alter sedimentation patterns in the mouths of harbours. As with other energy sources, it may become necessary to strike a balance between power production, ecological needs, and navigation requirements.[22] The effects on large animals will need to be monitored, especially for deployments in Cook Strait. However, water is over eight hundred times denser than air and tidal turbines rotate correspondingly slowly, reducing the direct risk to large animals.[20]

Lifecycle greenhouse gas emissions are predicted to be comparable to other renewable energy sources (and far below emissions from fossil fuel-sourced generation).[23] This will increase the competitiveness of marine power as climate costs are internalised by fossil fuel-sourced generation.

Climate change will effect marine resources
Climate change and variability represent complexities when trying to understand global oceanic processes. It is not clear how climate impacts will interact with changes from human activities such as over-fishing and pollution.[24] The physical impact of climate change on New Zealand waters will be varied, with overall increases in temperature and acidity. The resulting biological and socioeconomic impacts are yet to be fully understood but will be largely location-specific. Pronounced changes will occur due to the interplay between local ecosystem vulnerabilities, the direction and magnitude of environmental change, and human activities. These changes are expected to have a substantial impact on ocean management and marine industry but we cannot yet say where critical sites lie—a problem that NIWA's Ocean Climate Change Atlas project is aiming to address.[25]

Systemic uncertainty about marine resources
Research has identified extensive resources within our marine realm that directly or indirectly provide economic opportunities. Nevertheless, for the majority of New Zealand's continental shelf and Exclusive Economic Zone, researchers are still in the stage of discovering what is there. For land-based resources there is often sufficient information to enable management of activities to proceed in an informed and responsive fashion where impacts of activities can be predicted and easily monitored, and actions can be changed promptly in response to the impacts. For offshore resources there is limited information and monitoring about the nature, distribution, variability, and vulnerability of resources, species, habitats, and ecosystems. Therefore it is difficult to make sound resource management decisions in a consistent and evidence-supported manner without a great deal more understanding of the offshore environment. For instance, half of the EEZ is deeper than 2000 metres yet fewer than one hundred research bottom trawls have been made at those depths. For the region of the EEZ deeper than 4000 metres—an area more than four times the land area of New Zealand—no bottom exploration has been carried out.

The geographical distribution of marine biodiversity is also only partially understood, making biodiversity protection efforts difficult to focus. Only 0.3% of the EEZ is protected within reserves, amounting to 7.6% of the territorial sea (out to 12 nautical miles). A further 32% is protected from bottom trawling in Benthic Protected Areas. It is vital to ensure that such protection matches areas of high, rare, representative or critical biodiversity, covers all human activities, and has clear goals and demonstrable benefits.

New Zealand's capability to manage and benefit from our marine biodiversity is limited because of the constrained research base that underpins this capability. The capacity to even recognise and identify species continues to decline. Marine taxonomists have highlighted New Zealand's limited capacity for decades, with a 1989 DSIR report stating "scientific resources in… the biosystematics activity area have now been reduced to a level at which viability is marginal"[26] with the same message being repeated in 2006.[27] Our limited capacity to carry out baseline research is only one example of the systemic lack of research, to the point where it is difficult to see how any marine resource can be effectively managed or any a balance struck between competing uses. Improving the capability to monitor cumulative impacts, assess the vulnerabilities of ecosystems, inform on ecosystem health and integrity, and to understand socioeconomic values of marine areas will help the success of integrated planning of marine resource management.[2]

In conclusion – institutions matter

In just a few decades, the fisheries industry has transitioned from crisis to a substantial and long-term generator of wealth for New Zealand. As shown by New Zealand's experience with the fisheries Quota Management System, institutions matter. Our developing understanding of New Zealand ocean energy, minerals and petroleum, ecosystems and biodiversity all suggest that more potential sources of wealth are present in our oceans. However, appropriate management frameworks (i.e. institutions) are critical if New Zealand is to develop its marine resources efficiently and responsibly.

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Further content available online:

Fauvre & Wood "Physical Resources of New Zealand's Marine Estate", 2011

Boyd, *et al* "An Ocean Climate Change Atlas for New Zealand Waters", NIWA Information Series No 79, 2011

Power Projects Limited, "Development of Marine Energy in New Zealand", 2008

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