8.3. *Ocean climate trends and New Zealand fisheries*

This section has been quoted almost directly from the summary in Hurst *et al.* (2012). Some general observations on recent trends in some of the key ocean climate indices that have been found to be correlated with a variety of biological processes among fish (including recruitment fluctuations, growth, distribution, productivity and catch rates) are:

- The Interdecadal Pacific Oscillation (IPO): available from 1900; time scale 10–30 years. The IPO has been found to have been correlated with decadal changes ('regime shifts') in northeast Pacific ecosystems (e.g., Alaska salmon catches). In the New Zealand region, there is evidence of a regime shift into the negative phase of the IPO in about 2000. During the positive phase, from the late 1970's to 2000, New Zealand experienced periods of enhanced westerlies, with associated cooler air and sea temperatures and enhanced upwelling on western coasts. Opposite patterns are expected under a negative phase. For most New Zealand fisheries, monitoring of changes in populations began since the late 1970's, so there is little information on how New Zealand fishstocks might respond to these longer-term climatic fluctuations. Some of the recent changes in fish populations since the mid 1990s, for example, low western stock hoki recruitment indices (Francis 2009) and increases in some elasmobranch abundance indices (Dunn *et al.* 2009) may be shorter-term fluctuations that might be related in some way to regional warming during the period and only longer-term monitoring will establish whether they might be related to longer-term ecosystem changes.

- The Southern Oscillation Index: available from 1876; best represented as annual means. Causal relationships of correlations of SOI with fisheries processes are poorly understood but probably related in some way to one or more of the underlying ocean climate processes such as winds or temperatures. When the index is strongly negative, an El Niño event is taking place and New Zealand tends to experience increased westerly and south-westerly winds, cooler sea surface temperatures and enhanced upwelling in some areas (see, for example, the correlation of monthly SST at Leigh and SOI indices, Figure 8.13). Upwelling has been found to be related to increased nutrient flux and phytoplankton growth in areas such as the west coast South Island, Pelorus Sound and north-east coast of the North Island (Willis *et al.* 2007, Zeldis *et al.* 2008). El Niño events are likely to occur on 3–7 year time scales and are likely to be less frequent during the negative phase of the IPO which began in about 2000. This is likely to impact positively on species that show stronger recruitment under increased temperature regimes (e.g., snapper, Francis 1993, 1994a, b).

- Surface wind and pressure patterns: available from 1940s; variation in patterns can be high over monthly and annual time scales and many of the indices are correlated with each other, and with SOI and IPO indices (e.g., more zonal westerly winds, more frequent or regular cycles in southerlies in the positive IPO, 1977–2000). Correlations with biological process in fish stocks may occur over short time scales (e.g., impact on fish catchability) as well as seasonal and annual scales (e.g., impact on recruitment success). Wind and pressure patterns have been found to be correlated with fish abundance indices for southern gemfish (Renwick *et al.* 1998), hake, red cod and red gurnard (Dunn *et al.* 2008), rock lobster (Booth *et al.* 2000), and southern blue whiting (Willis *et al.* 2007, Hanchet & Renwick, 1999). Causal relationships of these correlations are poorly understood but can be factored into hypothesis testing as wind and pressure patterns affect surface ocean conditions through heat flux, upwelling and nutrient availability on exposed coasts.

- Temperature and sea surface height: available at least monthly over long time scales (air temperatures from 1906) or relatively short time scales (ocean temperatures to 800m, SST and SSH variously from 1987). Ocean temperatures, SST and SSH are all correlated with each other and smoothed air temperatures correlate well with SST in terms of interannual and seasonal variability; there are also some correlations of SST and SSH with surface wind and pressure patterns (see Dunn *et al.* 2009). SST has been found to be correlated with relative fish abundance indices (derived from fisheries and/or trawl surveys) for elephantfish, southern gemfish, hoki, red cod, red gurnard, school shark, snapper, stargazer and tarakihi (Francis 1994a,b, Renwick et al 1998, Beentjes & Renwick 2001, Gilbert & Taylor 2001, Dunn et al 2009). Air temperatures in New Zealand have increased since 1900; most of the increase occurred since the mid 1940s. Increases from the late 1970s to 2000 may have been moderated by the positive phase of the IPO. Coastal SST records from 1954 (at Portobello) also show a slight increase through the series and, in general, show strong correlations with SOI (i.e., cooler temperatures in El Niño years). Other time series (SSH, ocean temperature to 800m) are comparatively short but show cycles of warmer and cooler periods on 1–6 year time scales. All air and ocean temperature series show the significant warming event during the late 1990s which has been followed by some cooling, but not to the levels of the early 1990s.

- Ocean colour and upwelling: these will be important time series because they potentially have a more direct link to biological processes in the ocean and are more easily incorporated into hypothesis testing. The ocean colour series starts in late 1997, so is not able to track changes that may have occurred since before the late 1990s warming cycle. These indices also need to be analysed with respect to SST, SSH and wind patterns, at similar locations or on similar spatial scales. The preliminary series developed exhibit some important spatial differences and trends that may warrant further investigation in relation to fish abundance indices. Of note are the increased chlorophyll indices off the west and south-west coast of the South Island in spring/summer during the last 5–6 years and the relatively low upwelling indices off the west coast South Island during winter in the late-1990s (Hurst *et al.* 2012).

- Currents: there are no general indices of trends or variability at present. Improvements in monitoring technology (e.g., satellite observations of SSH; CTD; ADCP; ARGO floats) have resulted in more information becoming available to enable numerical models of ocean currents to be developed. On the open ocean scale, there is considerable complexity in the New Zealand zone (e.g., frontal systems, eddy systems of the east coast). In the coastal zone, this is further complicated in coastal areas by the effects of tides, winds and freshwater (river) forcing, and a more limited monitoring capability. Nevertheless, the importance of current systems is starting to become more recognised and incorporated into analysis and modelling of fisheries processes and trends. Recent examples include the retention of rock lobster phyllosoma (mid-stage larvae) in eddy systems (Chiswell & Booth 2005, 2007), the apparent bounding of orange roughy nursery grounds by the presence of a cold-water front (Dunn *et al.* 2009) and the drift of toothfish eggs and larvae (Hanchet *et al.* 2008).

- Acidification: The increase in atmospheric CO_2 has been paralleled by an increase in CO_2 concentrations in the upper ocean, resulting in a decrease in pH. Maintenance of the one existing New Zealand monitoring programme for pH and pCO_2, and development of new programmes to monitor the impacts of pH on key groups of organisms are critical. Potentially vulnerable groups include organisms that produce shells or body structures of calcium carbonate (corals, molluscs, plankton, coralline algae), and also non-calcifying groups including plankton, squid and high-activity pelagic fishes. Potentially positive impacts of acidification include increased phytoplankton carbon fixation and vertical export and increased productivity of sub-tropical waters due to enhanced nitrogen fixation by cyanobacteria. Secondary effects at the ecosystem level, such as productivity, biomass, community composition and biogeochemical feedbacks, also need to be considered.

Climate change was not specifically addressed as part of the report by Hurst *et al.* (2012), although indices described are an integral part of monitoring the speed and impacts of climate change. As noted under the air temperature section, the slightly increasing trend in temperatures since the mid 1940s is likely to have been moderated by the positive phase of the IPO, from the late 1970s to the late 1990s. With the shift to a negative phase of the IPO in 2000, it is likely that temperatures will increase more steeply. Continued monitoring of the ocean environment and response is critical. This includes not only the impacts on productivity, at all levels, but also on increasing ocean acidification.

For the New Zealand region, key ocean climate drivers in the last decade have been:

- the significant warming event in the late 1990s
- the regime shift to the negative phase of the IPO in about 2000, which is likely to result in fewer El Niño events for a 20–30 year period, i.e., less zonal westerly winds (already apparent compared to the 1980–2000 period) and increased temperatures; this is the first regime shift to occur since most of our fisheries monitoring time series have started (the previous shift was in the late 1970s), and
- global trends of increasing air and sea temperatures and ocean acidification.

8.4. *References*

Bates, N.R. 2001. Interannual variability of oceanic CO_2 and biogeochemical properties in the Western North Atlantic subtropical gyre. *Deep-Sea Research II.* 48:1507–1528.

Bates, N.R. 2007. Interannual variability of the oceanic CO_2 sink in the subtropical gyre of the North Atlantic Ocean over the last 2 decades. *J. Geophysical Res.* 112, C09013, doi:10.1029/2006JC003759, 2007

Beentjes, M.P., Renwick, J.A. 2001. The relationship between red cod, *Pseudophycis bachus*, recruitment and environmental variables in New Zealand. *Environmental Biology of Fishes 61*: 315–328.

Bowen, M. M., Sutton, P.J.H., Roemmich, D. 2006. Wind-driven and steric fluctuations of sea surface height in the southwest Pacific, *Geophys. Res. Lett., 33*, L14617, doi:10.1029/2006GL026160.

Brix, H; Gruber, N., Keeling, C.D. 2004. Interannual variability of the upper ocean carbon cycle at station ALOHA near Hawaii Global *Biogeochemical Cycles 18(4)* GB4019 Nov 24 2004.

Caldeira, K., Wickett, M.E. 2003. Anthropogenic carbon and ocean pH. *Nature* 425:365.

Chang, F.H., Mullan, B. 2003. Occurrence of major harmful algal blooms in New Zealand: is there a link with climate variation. *The Climate Update 53*: 4.

Chiswell SM 1996. Variability in the Southland Current, New Zealand. New Zealand Journal of Marine and Freshwater Research 30: 1-17.

Chiswell, S.M; Booth, J.D. 2005. Distribution of mid- and late-stage *Jasus edwardsii* phyllosomas: implications for larval transport. *New Zealand Journal of Marine and Freshwater Research 39*. 1157–1170.

Chiswell, S.M; Booth, J.D. 2007. Sources and sinks of larval settlement in *Jasus edwardsii* around New Zealand: Where do larvae come from and where do they go? *Marine Ecology Progress Series 354*: 201-217.

Clark, M.R. (1999). Fisheries for orange roughy (Hoplostethus atlanticus) on seamounts in New Zealand. Oceanologica Acta 22(6): 593-602

Dore, J.E., R. Lukas, D.W. Sadler, M.J. Church, and D.M. Karl. 2009. Physical and biogeochemical modulation of ocean acidification in the central North Pacific. Proceedings of the National Academy of Sciences of the United States of America 106(30):12,235–12,240.

Dunn, M.R.; Hurst, R.; Renwick J.; Francis, R.I.C.C.; Devine, J.; McKenzie, A. 2009 . Fish abundance and climate trends in New Zealand. New Zealand Aquatic Environment and Biodiversity Report No. 31. 75 p.

Feely, R. A.; Sabine, Christopher L.; Lee, Kitack; Berelson, Will; Kleypas, Joanie; Fabry, Victoria J.; Millero, Frank J. (2004). "Impact of Anthropogenic CO_2 on the CaCO3 System in the Oceans" (abstract). Science 305 (5682): 362–366. doi:10.1126/science.1097329. PMID 15256664

Feely, RA. Doney, SC. Cooley, SR. (2009). Ocean Acidification. Present conditions and future changes in a high CO_2 world. Oceanography Volume 22(4): 36-47.

Francis M.P. 1993. Does water temperature determine year class strength in New Zealand snapper (*Pagrus auratus*, Sparidae)? Fisheries Oceanography 2(2): 65–72.

Francis, M.P. 1994a. Growth of juvenile snapper, *Pagrus auratus* (Sparidae). *New Zealand Journal of Marine and Freshwater Research 28*: 201–218.

Francis, M.P. 1994b. Duration of larval and spawning periods in *Pagrus auratus* (Sparidae) determined from otolith daily increments. *Environmental biology of Fishes 39*: 137–152.

Franke, A. and Clemmesen, C. (2011). Effect of ocean acidification on early life stages of Atlantic herring (Clupea harengus L.). Biogeosciences Discuss., 8, 7097– 7126.

Gilbert D.J., Taylor, P.R. 2001. The relationship between snapper (*Pagrus auratus*) year class strength and temperature for SNA2 and SNA7. New Zealand Fisheries Assessment report 2001/64. 33p.

Gordon DP, Beaumont J, MacDiarmid A, Robertson DA, Ahyong ST (2010) Marine Biodiversity of Aotearoa New Zealand. PLoS ONE 5(8): e10905. doi:10.1371/journal.pone.0010905

Hanchet, S. M., Renwick, J. A. 1999: Prediction of year class strength in southern blue whiting (Micromesistius australis) in New Zealand waters. *New Zealand Fisheries Assessment Research Document 99/51*. 24 p.

Hanchet, S.M., Fenaughty, J.M., Dunn, A., Williams, M.J.H. 2008. A hypothetical life cycle for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea region *CCAMLR Science 15*: 35–53.

Heath RA 1985. A review of the physical oceanography of the seas around New Zealand.1982. New Zealand Journal of Marine and Freshwater Research 19: 79.124.

Hobday, A.J, Okey, T.A, Poloczanska, E.S., Kunz, T.J., Richardson, A.J. 2006. Impacts of Climate Change on Australian Marine Life. CSIRO Marine and Atmospheric Research report to the Department of the Environment and Heritage

Houghton J.T., Ding, Y., Griggs, D.J., Noguer, M. van der Linden, P.J., Dai, X., Maskaell, K., Johnson, C.A. 2001. Climate change 2001: the scientific basis. Contribution of Working Group I to the third Assessment. Report of the International Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Hurst, R.J. Renwick, J.A. Sutton, P.J.H Uddstrom, M.J. Kennan, S.C. Law, C.S. Rickard, G.J. Korpela, A. Stewart, C. Evans J. (2012In press). Climate and oceanographic trends of potential relevantce to fisheries in the New Zealand fisheriesRegion, 2010. *New Zealand Aquatic Environment and Biodiversity Report No. 90XX*. 202p.

IPCC Third Assessment Report "Climate Change 2001".

Langer, G., M. Geisen, K.-H. Baumann, J. Kläs, U. Riebesell, S. Thoms, Young, J. R. 2006. Species-specific responses of calcifying algae to changing seawater carbonate chemistry, *Geochem. Geophys. Geosyst., 7* : Q09006, doi:10.1029/2005GC001227

Lutz MJ, Caldeira K, Dunbar RB, Behrenfeld MJ (2007) Seasonal rhythms of net primary production and particulate organic carbon flux to depth describe the efficiency of biological pump in the global ocean. J Geophys Res Oceans 112:C10011 doi: 10.1029/2006JC003706

Mullan, A. B., 1995. On the linearity and stability of Southern Oscillation-climate relationships for New Zealand. *Internatinal Journal of Climatology 15*: 1365–1386.

Mullan, A.B; Stuart, S.J; Hadfield, M.G; Smith, M.J (2010). Report on the Review of NIWA's 'Seven-Station' Temperature Series NIWA Information Series No. 78. 175 p.

O'Driscoll, R.L.; Hurst, R.J.; Dunn, M.R.; Gauthier, S.; Ballara, S.L. (2011). Trends in relative mesopelagic biomass using time series of acoustic backscatter data from trawl surveys.*New Zealand Aquatic Environment and Biodiversity Report 2011/76*.

Orr, J.C., Fabry, V.J., Aumont, O., Bopp, L., Doney, S.C., Feely, R.A., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R.M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R.G., Plattner, G-K ., Rodgers, K.B., Sabine, C.L., Sarmiento, J.L., Schlitzer, R., Slater, R.D., Totterdell, I.J., Weirig, M-F., Yamanaka, Y., Yool, A. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437: 681–686. *Global Biogeochemical Cycles 21*: GB2028, doi:10.1029/2006GB002898, 2007

Philip W. Boyd & Cliff S. Law (2011). An Ocean Climate Change Atlas for New Zealand waters A primer for a major new web-based tool to help predict how oceanic species will be affected by climate change NIWA Information Series No. 79 ISSN 1174-264X

Pinkerton, M.H., Richardson, K.M., Boyd, P.W., Gall, M.P., Zeldis, J., Oliver, M.D., Murphy, R.J. 2005. Intercomparison of ocean colour band-ratio algorithms for chlorophyll concentration in the Subtropical Front east of New Zealand. *Remote Sensing of Environment 97*: 382–402.

Reid JL 1986. On the total geostrophic circulation of the South Pacific Ocean: flow patterns, tracers and transports. Progress in Oceanography 16: 1-61.

Renwick, J.A., Hurst, R.J., Kidson, J.W. 1998: Climatic influences on the recruitment of Southern Gemfish (*Rexea solandri*, Gempylidae) in New Zealand waters. *International Journal of Climatology* 18: 1655–1667.

Reynolds, R.W., Smith, T.M.; Liu, C.; Chelton, D.B.; Casey, K.S.; Schlax, M.G. (2007). Daily High-resolution Blended Analyses for sea surface temperature. Journal of Climate, 20, 5473-5496.

Ridgway KR, Dunn JR 2003. Mesoscale structure of the mean East Australian Current system and its relationship with topography. Progress in Oceanography 56: 189.222.

Roemmich, D., Gilson, J.,K, Davis, R., Sutton, P., Wijffels, S., Riser, S. 2007. Decadal Spin-up of the South Pacific Subtropical Gyre. *Journal of Physical Oceanography 37: 162–173.*

Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C.S., Wallace, D.W., Tilbrook, B., Millero, F.J., Peng, T.H., Kozyr, A. Ono,. T., Rios, A.F. 2004. The oceanic sink for anthropogenic CO_2. Science 305:367–371.

Shirtcliffe, G.G.L., Moore, M.I., Cole, A.G., Viner, A.B., Baldwin, R. Chapman, B. 1990. Dynamics of the Cape Farewell upwelling plume, New Zealand. New Zealand *Journal of Marine and Freshwater Research 24*: 555–568.

Stanton BR 1981. An oceanographic survey of the Tasman Front. New Zealand Journal of Marine and Freshwater Research 15: 289-297.

Stanton BR, Ridgway NM 1988. An oceanographic survey of the subtropical convergence zone in the Tasman Sea. New Zealand Journal of Marine and Freshwater Research 22: 583-593.

Stanton BR, Sutton PJH, Chiswell SM 1997. The East Auckland Current, 1994.95. New Zealand Journal of Marine and Freshwater Research 31: 537-549.

Sutton PJH 2003. The Southland Current: a subantarctic current. New Zealand Journal of Marine and Freshwater Research 37: 645--652.

Sutton, P., Bowen, M., Roemmich, D. 2005. Decadal Temperature changes in the Tasman Sea. *N.Z. Journal of Marine and Freshwater Research 39(6)*: 1321–1329.

Sutton, P.J.H.; Roemmich, D.; 2001. Ocean temperature climate off north-east New Zealand. *N.Z. Journal of Marine and Freshwater Research 35: 553–565.*

Sutton, R.T.; Dong, B.; Gregory, J.M. (2007). Land/sea warming ratio in response to climate change: IPCC AR4 model results and comparison with observations. Geophysical Research Letters, 34, L02701, doi:10.1029/2006GL028164.

Thompson, D.W.J.; Solomon, S. (2002). Interpretation of recent Southern Hemisphere climate change. Science, 296, 895-899.

Thompson, P.A.; Baird, M.E.; Ingleton, T.; Doblin, M.A. (2009). Long-term changes in temperature Australian waters: implications for phytoplankton. Marine Ecology Progress Series, 394, 1-19.

Thresher, R.E., Guinotte, J., Matear R., Fallon S. (2012). Adapting to the effects of climate change on Australia's deep marine reserves. Fisheries Research and Development Corporation (FRDC)/National Climate Change Adaptation Research Fund (NCCARF) Report 2010/510, 68 p.

Tracey, D.M., Rowden, A.A., Mackay, K.A., Compton, T (2011) Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. Mar Ecol Prog Ser 430: 1–22Francis R.I.C.C. 2009. Assessment of hoki (*Macruronus novaezelandiae*) in 2008. New Zealand Fisheries Assessment Report 2009/7. 80p.

Willis, T.J., Handley, S.J., Chang, F.H., Morrisey, D.J., Mullan, B., Pinkerton, M., Rodgers, K.L., Sutton, P.H.J., Tait, A. 2007. Climate change and the New Zealand marine environment. NIWA Client Report for the Department of Conservation: NEL2007-025 October 2007, NIWA Project: DOC08305

Zeldis, J.R, Howard-Williams, C, Carter, C.M., Schiel, D.R. 2008. ENSO and riverine control of nutrient loading, phytoplankton biomass and mussel aquaculture yield in Pelorus Sound, New Zealand. http://www.int-res.com/articles/meps2008/371/m371p131.pdf

Zeldis, J.R. 2004. New and remineralised nutrient supply and ecosystem metabolism on the northeastern New Zealand continental shelf. *Continental Shelf Research 24*: 563–581.

9. Habitats of particular significance for fisheries management

Scope of chapter	This chapter highlights subject areas that might contribute to the management of HPSFM and hence provides a guide for future research in the absence of an approved policy definition of HPSFM
Area	All of the New Zealand EEZ and territorial sea (inclusive of the freshwater and estuarine areas).
Locality hotspots	None formally defined, but already identified likely candidates include areas of biogenic habitat, e.g. Separation Point and Wairoa Hard, and areas identified with large catches and/or vulnerable populations of juveniles, e.g. Hoki Management Areas, packhorse crayfish legislated closures and toheroa beaches.
Key issues	Defining and identifying likely HPSFM and potential threats to them.
Emerging issues	Connectivity and intra-population behaviour variability, multiple use
MPI Research (current)	Biogenic habitats as areas of particular significance for fisheries management (HAB2007/01), Toheroa abundance (TOH2007/03), Research on Biogenic Habitat-Forming Biota and their functional role in maintaining Biodiversity in the Inshore Region (5-150M Depths) (ZBD2008/01 – this is also part-funded by Oceans Survey 2020, NIWA and MBIE) , Habitats of particular significance for fisheries management: Kaipara Harbour (ENV2009/07), Habitats of particular significance for inshorefinfish fisheries management (ENV2010/03) Spatial Mixing of GMU1 using Otolith Microchemistry (GMU2009/01).
NZ Government Research (current)	Ministry of Business, Innovation and Employment (MBIE) funded programmes (Coastal Conservation Management: protecting the functions of marine coastal habitats that support fish assemblages at local, regional and national scales (C01X0907) Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region (C01X1229) and Impacts of resource use on vulnerable deep-sea communities (C01X0906). NIWA Core funding in the ’Managing marine stressors’ area under the ’Coasts and Oceans’ centre, specifically the programme ’Managing marine resources’ and the project ’Measuring mapping and conserving (C01X0505)’
Links to 2030 objectives	Under the Environment Outcome habitats of special significance to fisheries need to be protected.
Related chapters/issues	Land-based impacts on fisheries and supporting biodiversity, bycatch composition, marine environmental monitoring.

9.1. *Context*

The Fisheries Act 1996, in Section 9 (Environmental principles) states that:

> “*All persons exercising or performing functions, duties, or powers under this Act, in relation to the utilisation of fisheries resources or ensuring sustainability, shall take into account the following environmental principles:*
> *(a) Associated or dependent species should be maintained above a level that ensures their long-term viability:*
> *(b) Biological diversity of the aquatic environment should be maintained:*

(c) Habitat of particular significance for fisheries management should be protected."

No policy definition of habitat of particular significance for fisheries management (HPSFM) exists, although work is currently underway to generate one. Some guidance in terms of defining HPSFM is provided by Fisheries 2030 which specifies as an objective under the Environment Outcome that "*habitats of special significance to fisheries are protected*". This wording suggests that a specific focus on habitats that are important for fisheries production should be taken rather than a more general focus that might also include other habitats that may be affected by fishing.

Fisheries 2030 re-emphasises that HPSFM should be protected. No specific strategic actions are proposed to implement this protection in Fisheries 2030; although action 6.1 "To implement a revised MPA policy and legal framework" could potentially be relevant to protecting HPSFM. The management of activities other than fishing, such as land-use and vehicle traffic, are outside the control of the Ministry for Primary Industries but Fisheries 2030 specifies actions to "Improve fisheries sector input to processes that manage RMA-controlled effects on the marine and freshwater environment" (Action 8.1) and to "Promote the development and use of RMA national policy statements, environmental standards, and regional coastal and freshwater plans" (Action 8.2). This suggests that the cooperation of other parties outside of the fisheries sector may be necessary in some cases to protect HPSFM.

In the absence of a policy definition of HPSFM this chapter will focus on examples of habitats shown to be important for fisheries and concepts likely to be important to HPSFM. Examples of potential HPSFM include: sources of larvae; larval settlement sites; habitat for juveniles; habitat that supports important prey species; migration corridors; and spawning, pupping or egg-laying grounds. Some of these habitats may be important for only part of the life cycle of an organism, or for part of a year.

The location or relative importance of habitats, compared with other limiting factors, is largely unknown for most stocks. For example, some stocks may be primarily habitat limited, whereas others may be limited by oceanographic variability, food supply, predation rates (especially during juvenile phases), or a mixture of these and other factors. In the case of stocks that are habitat limited, a management goal might be to preserve or improve some aspect of the habitat for the stock.

Hundreds of legislated spatial fisheries restrictions already apply within New Zealand's territorial sea and exclusive economic zone (www.nabis.govt.nz), but until further policy work and research is conducted we cannot be sure the contribution they make to protecting HPSFM. Examples of these are listed below:

- Separation Point in Tasman Bay, and the Wairoa Hard in Hawke Bay, were created to protect biogenic habitat which was believed to be important as juvenile habitat for a variety of fish species (Grange *et al.* 2003).

- An area near North Cape is currently closed to packhorse lobster fishing to mitigate sub-legal handling disturbance in this area. This closure was established because of the small size of lobsters caught there and a tagging study that showed movement away from this area into nearby fished areas (Booth 1979).

- The largest legislated closure are the Benthic Protection Areas (BPAs) which protect ~ 1.2 million square km (about 31% of the EEZ) outside the territorial sea from contact of trawl and dredge gear with the bottom (Helson *et al.* 2010).

- Commercial fishers must not use New Zealand fishing vessels or foreign-owned New Zealand fishing vessels over 46 m in overall length for trawling in the territorial sea.

In addition to legislated closures, a number of non-regulatory management measures exist. For example:

- Spatial closures
  - Trawlers greater than 28 m in length are excluded from targeting hoki in four Hoki Management Areas – Cook Strait, Canterbury Banks, Mernoo Bank, and Puysegur Bank (DeepWater Group 2008). These areas were chosen because of the larger number of juveniles caught, relative to adults in these areas.
  - Trawling and pair trawling are both closed around Kapiti Island

- Seasonal closures
  - A closure to trawling exists from November the first until the 30th of April each year in Tasman Bay.
  - A closure to commercial potting exists for all of CRA3 for the whole of the month of December each year.

The high-level objectives and actions in Fisheries 2030 have been interpreted in the highly migratory, deepwater and middle-depths (deepwater) inshore national fish plans. The highly migratory fish plan addresses HPSFM in environment outcome 8.1 "Identify and where appropriate protect habitats of particular significance to highly migratory species, especially within New Zealand waters". In the deepwater fish plan the Ministry proposes in management objective 2.3 "to develop policy guidelines to determine what constitutes HPSFM then apply these policy guidelines to fisheries where necessary". Inshore fisheries management plans (freshwater, shellfish and finfish) all contain references to identifying and managing HPSFM. These plans recognise that not all impacts stem from fisheries activities, therefore managing them may include trying to influence others to better manage their impacts on HPSFM. Work is underway on a policy definition of HPSFM that will assist implementing these outcomes and objectives.

9.2. *Global understanding*

This section focuses upon those habitats protected overseas for their value to fisheries and discusses important concepts that may help gauge the importance of any particular habitat to fisheries management. This information may guide future research into HPSFM in New Zealand and any subsequent management action.

9.2.1. Habitats protected elsewhere for fisheries management

Certain habitats have been identified as important for marine species: shallow sea grass meadows, wetlands, seaweed beds, rivers, estuaries, rhodolith beds, rocky reefs, crevices, boulders, bryozoans, submarine canyons, seamounts, coral reefs, shell beds and shallow bays or inlets (Kamenos *et al.* 2004; Caddy 2008, Clark 1999, Morato *et al.* 2010). Discrete habitats (or parts of these) may have extremely important ecological functions, and/or be especially vulnerable to degradation. For example, seabeds with high roughness are important for many fisheries and can be easily damaged by interaction with fishing gear (Caddy 2008). Examples of these include:

1. The *Oculina* coral banks off Florida were protected in 1994 as an experimental reserve in response to their perceived importance for reef fish populations (Rosenberg *et al.* 2000). Later studies confirmed that this area is the only spawning aggregation site for gag (*Mycteroperca microlepis*) and scamp (*M. phenax*) (both groper species), and other economically important reef fish in that region (Koenig *et al.* 2000). The size of the area within which bottom-tending gears were restricted was subsequently increased based on these findings (Rosenberg *et al.* 2000).

2. *Lophelia* cold-water coral reefs are now protected in at least Norway (Fosså *et al.* 2002), Sweden (Lundälv, & Jonsson 2003) and the United Kingdom (European Commission 2003) due to their importance as habitat for many species of fish (Costello *et al.* 2005).
3. The Western Pacific Regional Fishery Management Council identified all escarpments between 40 m and 280 m as Habitat Areas of Particular Concern (HAPC) for species in the bottom-fish assemblage. The water column to a depth of 1000 m above all shallow seamounts and banks was categorised as HAPC for pelagic species. Certain northwest Hawaiian Island banks shallower than 30 m were categorised as HAPC for crustaceans, and certain Hawaiian Island banks shallower than 30 m were classified as Essential Fish Habitat (EFH) for precious corals. Fishing is closely regulated in the precious-coral EFH, and harvest is only allowed with highly selective gear types which limit impacts, such as manned and unmanned submersibles (West Pacific Fisheries Management Council 1998)

Examples of habitats protected for their freshwater fishery values also exist. For example, the U.S. Atlantic States Interstate fishery management plan (Atlantic States Marine Fisheries Commission 2000) notes the Sargasso Sea is important for spawning, and that seaweed harvesting provides a threat of unknown magnitude to eel spawning. Habitat alteration and destruction are also listed as probably impacting on continental shelves and estuaries/rivers, respectively, but the extent to which these are important is unknown.

It is also possible that HPSFM may be defined by the functional importance of an area to the fishery. For example, large spawning aggregations can happen in mid-water for set periods of time (Schumacher and Kendall 1991, Livingston 1990) these could also potentially qualify as HPSFM.

9.2.2. Concepts potentially important for HPSFM

Many nations are now moving towards formalised habitat classifications for their coastal and ocean waters, which may include fish dynamics as part of their structure, and could potentially help to define HPSFM. Such systems help provide formal definitions for management purposes, and to 'rank' habitats in terms of their relative values and vulnerability to threats. Examples include the Essential Fish Habitat (EFH) framework being advanced in North America (Benaka 1999, Diaz *et al.* 2004, Valavanis *et al.* 2008), and in terms of habitat, the developing NOAA Coastal and Marine Ecological Classification Standard for North America (CMECS) (Madden *et al.* 2005, Keefer *et al.* 2008), and the European Marine Life Information Network (MarLIN) framework which has developed habitat classification and sensitivity definitions and rankings (Hiscock and Tyler-Walters 2006).

Habitat connectivity (the movement of species between habitats) operates across a range of spatial scales, and is a rapidly developing area in the understanding of fisheries stocks. These movements link together different habitats into 'habitat chains', which may also include 'habitat bottlenecks', where one or more spatially restricted habitats may act to constrain overall fish production (Werner *et al.* 1984). Human driven degradation or loss of such bottleneck habitats may strongly reduce the overall productivity of populations, and hence ultimately reduce long-term sustainable fisheries yields. The most widely studied of these links is between juvenile nursery habitats and often spatially distant adult population areas. Most studies published have been focussed on species that uses estuaries as juveniles; e.g. blue grouper *Achoerodus viridis* (a large wrasse) (Gillanders and Kingsford 1996) and snapper *Pagrus auratus* (Hamer *et al.* 2005) in Australia; and gag (*Mycteroperca-Microlepis*) in the United States (Ross and Moser 1995) which make unidirectional ontogenetic habitat shifts from estuaries and bays out to the open coast as they grow from juveniles to adults. The extent of wetland habitats in the Gulf of Mexico has also been linked to the yield of fishery species dependent on coastal bays and estuaries. Reduced fishery stock production (shrimp and menhaden (a fish)) followed wetland losses and, conversely, stock gains followed increases in the area of wetlands (Turner and Boesch 1987). Juvenile production was limited by the amount of available habitat but, equally, reproduction, larval settlement, juvenile or adult survivorship, or other demographic factors could also be limited by habitat loss or degradation, and these could have knock-on effects to stock characteristics such as productivity and its variability. Other examples include movements which may be bidirectional and regular in nature e.g., seasonal migrations of adult fish to and from spawning and/or feeding grounds, e.g. grey mullet *Mugil cephalus* off Taiwan (Chang *et al.* 2004).

How habitats are spatially configured to each other is also important to fish usage and associated fisheries production. For example, Nagelkerken *et al.* (2001) showed that the presence of mangroves in tropical systems significantly increases species richness and abundance of fish assemblages in adjacent seagrass beds. Jelbart *et al.* (2007) sampled Australian temperate seagrass beds close to (< 200 m) and distant from (> 500 m) mangroves. They found seagrass beds closer to mangroves had greater fish densities and diversities than more distant beds, especially for juveniles. Conversely, the densities of fish species in seagrass at low tide that were also found in mangroves at high tide were negatively correlated with the distance of the seagrass bed from the mangroves. This shows the important daily habitat connectivity that exists through tidal movements between mangrove and seagrass habitats. Similar dynamics may occur in more sub-tidal coastal systems at larger spatial and temporal scales. For example, Dorenbosch *et al.* (2005) showed that adult densities of coral reef fish, whose juvenile phases were found in mangrove and seagrass nursery habitats, were much reduced or absent on coral reefs located far distant from such nursery habitats, relative to those in closer proximity.

A less studied, but increasingly recognised theme is the existence of intra-population variability in movement and other behavioural traits. Different behavioural phenotypes within a given population have been shown to be very common in land birds, insects, mammals, and other groups. An example of this is a phenomenon known as 'partial migration', where part of the overall population migrates each year, often over very large distances, while another component does not move and remains resident. By definition, this partial migration also results in differential use of habitats, often over large spatial scales. Recent work on white perch (*Morone americana*) in the United States shows this population is made up of two behavioural components: a resident natal freshwater contingent; and a dispersive brackish-water contingent (Kerr *et al.* 2010). The divergence appears to be a response to early life history experiences which influence individuals' growth (Kerr 2008). The proportion of the overall population that becomes dispersive for a given year class ranges from 0% in drought years to 96% in high-flow years. Modelling of how differences in growth rates and recruitment strengths of each component contributed to the overall population found that the resident component contributed to long-term population persistence (stability), whereas the dispersive component contributed to population productivity and resilience (defined as rebuilding capacity) (Kerr *et al.* 2010). Another species winter flounder *Pseudopleuronectes americanus* has also shown intra-population variability in spawning migrations; one group stays coastally resident while a second smaller group migrate into estuaries to spawn (DeCelles & Cadrin 2010). The authors went on to suggest that coastal waters in the Gulf of Maine should merit consideration in the assignment of Essential Fish Habitat for this species.

Kerr and Secor (2009) and Kerr *et al.* (2010) argue that such phenotypic dynamics are probably very common in marine fish populations but have not yet been effectively researched and quantified. The existence of such dynamics would have important implications for fisheries management, including the possibility of spatial depletions of more resident forms and variability in the use of potential HPSFM between years. For instance, recent work on snapper in the Hauraki Gulf has shown that fish on reef habitats are more resident (ie have less propensity to migrate) than those of soft sediment habitats, and can experience higher fishing removals (Parsons *et al.* 2011).

The most effective means of protecting a HPSFM in terms of the benefit to the fishery may differ depending on the life-history characteristics of the fish. A variety of modelling, theoretical, and observational approaches have lead to the conclusion that spatial protection performs best at enhancing species whose adults are relatively sedentary but whose larvae are broadcast widely (Chiappone and Sealey 2000, Murawski *et al.* 2000, Roberts 2000, Warner *et al.* 2000). The sedentary habit of adults allows the stock to accrue the maximum benefit from the protection, whereas the broadcasting of larvae helps 'seed' segments of the population outside the protection. However, the role of spatial protection in directly protecting juveniles after they have settled to seafloor habitats (via habitat protection/recovery, and/or reduced juvenile bycatch), or their interaction with non-fisheries impacts has not yet been explicitly considered.

9.3. *State of knowledge in New Zealand*

9.3.1. Potential HPSFM in New Zealand

Important areas for spawning, pupping, and egg-laying are potential HPSFM. These areas (insofar as these are known) have been identified and described using science literature and fisheries databases and summarised within two atlases, one coastal (< 200 m) and one deepwater (> 200 m). Coastally, these HPSFM areas were identified for 35 important fish species by Hurst *et al.* (2000). This report concluded that virtually all coastal areas were important for these functions for one species or other. The report also noted that some coastal species use deeper areas for these functions, either as juveniles, or to spawn (e.g., red cod, giant stargazer) and some coastal areas are important for juveniles of deeper spawning species (e.g., hake and ling). Some species groupings were apparent from this analysis. Elephant fish, rig, and school shark all preferred to pup or lay eggs in shallow water, and very young juveniles of these species were found in shallow coastal areas. Juvenile barracouta, jack mackerel (*Trachurus novaezelandiae*), kahawai, rig, and snapper were all relatively abundant (at least occasionally) in the inner Hauraki Gulf. Important areas for spawning, pupping, and egg-laying were identified for 32 important deepwater fish species (200 to 1500 m depth), 4 pelagic fish species, 45 invertebrate groups, and 5 seaweeds (O'Driscoll *et al.* 2003). This study concluded that all areas to 1500 m deep were important for either spawning or juveniles of one or more species studied. The relative significance of areas was hard to gauge because of the variability in the data, however the Chatham Rise was identified as a "hotspot".

Areas of high juvenile abundances of certain species may be useful indicators of HPSFM for some species. A third atlas (Hurst *et al.* 2000b) details species distributions (mainly commercial) of adult and immature stages from trawl, midwater trawl and tuna longline where adequate size information was collected. No conclusions are made in this document, and generalisations across species are inherently difficult, therefore like the previous two atlases, this document is probably best examined for potential HPSFM in a species specific way.

Certain locations within New Zealand already seem likely to qualify as HPSFM under any likely definition. The Kaipara Harbour has been identified as particularly important for the SNA 8 stock. Analysis of otolith chemistry showed that, for the 2003 year-class, a very high proportion of new snapper recruits to the SNA 8 stock were sourced as juveniles from the Kaipara Harbour (Morrison *et al.* 2008). This result is likely to be broadly applicable into the future as the Kaipara provides most of the biogenic habitat available for juvenile snapper on this coast. The Kaipara and Raglan harbours also showed large catches of juvenile rig and the Waitemata, Tamaki and Porirua harbours moderate catches (Francis *et al.* 2012). Recent extensive fish-habitat sampling within the harbour in 2010 as part of the MBIE Coastal Conservation Management programme showed juvenile snapper to be strongly associated with sub-tidal seagrass, horse mussels, sponges, and an introduced bryozoan. Negative impacts on such habitats have the potential to have far-field effects in terms of subsequent fisheries yields from coastal locations well distant from the Kaipara Harbour. Beaches that still retain substantive toheroa populations, e.g. Dargaville and Oreti beaches, may also potentially qualify as HPSFM (Beentjes 2010).

Consistent with the international literature, biogenic (living, habitat forming) habitats have been found to be particularly important juvenile habitat for some coastal fish species in New Zealand. For example: bryozoan mounds in Tasman Bay are known nursery grounds for snapper, tarakihi and john dory (Vooren 1975); northern subtidal seagrass meadows fulfil the same role for a range of fish including snapper, trevally, parore, garfish and spotties (Francis *et al.* 2005, Morrison *et al.* 2008, Schwarz *et al.* 2006, Vooren 1975); northern horse mussel beds for snapper and trevally (Morrison *et al.* 2009); and mangrove forests for grey mullet, short-finned eels, and parore (Morrisey *et al.* 2010). Many other types of biogenic habitats exist, and some of their locations are known (e.g. see Davidson *et al.* 2010 for biogenic habitats in the Marlborough Sounds), but their precise role as HPSFM remains to be quantified. Examples include open coast bryozoan fields, rhodoliths, polychaete (worm) species ranging in collective form from low swathes to large high mounds, sea pens and sea whips, sponges, hydroids, gorgonians, and many forms of algae, ranging from low benthic forms such as *Caulerpa* spp. (sea rimu) through to giant kelp (*Macrocystis pyrifera*) forests in cooler southern waters. Similarly, seamounts are well-known to host reef-like formations of deep-sea stony corals (e.g., Tracey *et al.* 2011), as well as being major spawning or feeding areas for commercial deepwater species such as orange roughy and oreos (e.g., Clark 1999, O'Driscoll & Clark 2005). However, the role of these benthic communities on seamounts in supporting fish stocks is uncertain, as spawning aggregations continue to form even if the coral habitat is removed by trawling (Clark & Dunn 2012). Hence the oceanography or physical characteristics of the seamount and water column may be the key drivers of spawning or early life-history stage development, rather than the biogenic habitat.

Freshwater eels are reliant upon rivers as well as coastal and oceanic environments. GIS modelling estimates that for longfin eels, about 30% of longfin habitat in the North Island and 34% in the South Island is either in a reserve or in rarely/non-fished areas, with ~ 49% of the national longfin stock estimate of about 12 000 tonnes being contained in these waterways (Graynoth *et al.* 2008). More regional examination of the situation for eels also exists, e.g., for the Waikato Catchment (Allen 2010). Shortfin eels prefer slower-flowing coastal habitats such as lagoons, estuaries, and lower reaches of rims (Beentjes *et al.* 2005). In-stream cover (such as logs and debris) has been identified as important habitat, particularly in terms of influencing the survival of large juvenile eels (Graynoth *et al.* 2008). Short-fin eel juveniles and adults have also been found to be relatively common in estuarine mangrove forests, and their abundance positively correlated with structural complexity (seedlings, saplings, and tree densities) (Morrisey *et al.* 2010). In addition oceanic spawning locations are clearly important for eels, the location of these are unknown, although it has been suggested that these may be northeast of Samoa and east of Tonga for shortfins and longfins respectively (Jellyman 1994).

Many of the potential HPSFM are threatened by either fisheries or land-based effects, the reader should look to the land-based effects chapter in this document and the eel section of the Stock assessment plenary report for further details.

9.3.2. Habitat classification and prediction of biological characteristics

Habitat classification schemes focused upon biodiversity protection have been developed in New Zealand at both national and regional scales, these may help identify larger habitats which HPSFM may be selected from, but are unlikely to be useful in isolation for determining HPSFM. The Marine Environment Classification (MEC), the demersal fish MEC and the benthic optimised MEC (BOMEC) are national scale classification schemes have been developed with the goal of aiding biodiversity protection (Leathwick *et al.* 2004, 2006, 2012). A classification scheme also exists for New Zealand's rivers and streams based on their biodiversity values to support the Department of Conservations Waters of National Importance (WONI) project (Leathwick and Julian 2008). Regional classification schemes also exist such as ones mapping the Marine habitats of Northland, or Canterbury in order to assist in Marine Protected Area planning (Benn 2009; Kerr 2010).

Another tool which may help in terms of identifying HPSFM is the predictions of richness, occurrence and abundance of small fish in New Zealand estuaries (Francis *et al.* 2011). This paper contains richness predictions for 380 estuaries and occurrence predictions for 16 species. This could help minimise the need to undertake expensive field surveys to inform resource management, although environmental sampling may still be needed to drive some models.

9.3.3. Current research

Prior to 2007 research within New Zealand has not been explicitly focused on identifying HPSFM. However, in line with international trends, this situation has changed in recent times, with recognition of some of the wider aspects of fisheries management and the move towards an ecosystem approach foreshadowed in Fisheries 2030.

A number of Ministry and other research projects are underway, or planned, concerning HPSFM in the 2010/11 year. Project ENV200907, “Habitat of particular significance to fisheries management: Kaipara Harbour”, is underway and has the overall objective of identifying and mapping areas and habitats of particular significance in the Kaipara Harbour which support coastal fisheries; and identifying and assessing threats to these habitats. Included in this work is the reconstruction of environmental histories through interviews of long time local residents who have experience of the harbour, and associated collation and integration of historical data sources (e.g., catch records, photographs, diaries, maps, and fishing logs). Another output of this work will be recommendations on the best habitats and methods of monitoring to detect change to HPSFM within Kaipara harbour.

Biogenic habitats on the continental shelf from ~5 to 150 m depths are currently being characterised and mapped through the biodiversity project ZBD2008/01, this will also provide new information on fisheries species utilisation of these habitats. Interviews with 50 retired fishers have provided valuable information on biogenic habitat around New Zealand. A national survey to examine the present occurrences and extents of these biogenic habitats was completed in 2011 in collaboration with Oceans Survey 2020, NIWA and Ministry of Business, Innovation and Employment (MBIE) funding.

A number of other national scale projects are also underway. A desktop review is collating information on the importance of biogenic habitats to fisheries across the entire Territorial Sea and Exclusive Economic Zone (project HAB2007/01). A project has been approved to review the literature and recommend the relative urgency of research on habitats of particular significance for inshore finfish species (project ENV2010/03).

The Ministry of Business, Innovation and Employment (MBIE) funded project Coastal Conservation Management started in 2009 and runs for six years. This programme aims to integrate and add to existing fish-habitat association work to develop a national scale marine fish-habitat classification and predictive model framework. This project will also attempt to develop threat assessments at local, regional and national scales. MPI is maximising the synergies between its planned research and this project. As part of that synergy, work on the connectivity and stock structure of grey mullet (*Mugil cephalus*) is underway in collaboration with MFish project GMU2009/01. Otolith chemistry is being assessed for its utility in partitioning the GMU 1 stock into more biologically meaningful management units, and in quantifying the suspected existence of source and sink dynamics between the various estuaries that hold juvenile grey mullet nursery habitats.

MBIE also funded in 2012 the three year project delivered by NIWA entitled Predicting the occurrence of vulnerable marine ecosystems for planning spatial management in the South Pacific region. The development of predictive models of species occurrence under this project may also aid in identifying HPSFM. Identification of biogenic habitat has been part of the MBIE project “Vulnerable deep-sea communities”since 2009 (and its predecessor seamount programme) which includes survys of a range of habiatts that may be important for various life-history stages of commercial fish species: seamounts, canyons, continental slope, hydrothermal vents, seeps.

9.4. *Indicators and trends*

As no HPSFM are defined this section cannot be completed.

9.5. *References*

Allen M., Rosell R., Evans D. 2006. Predicting catches for the Lough Neagh (Northern Ireland) eel fishery based on stock inputs, effort and environmental variables. Fisheries Management and Ecology (13): 251-260.

Allen D. 2010. Eels in the Waikato Catchment. Client report prepared for Mighty River Power Ltd. 105p.

Atlantic States Marine Fisheries Commission 2000. Interstate Fishery Management Plan for American Eel. Fishery Management Report No. 36 of the Atlantic States Marine Fisheries Commission. 93p.

Benaka L. (Ed.) 1999. Fish habitat: essential fish habitat and rehabilitation, American Fisheries Society, Bethesda, MD. 45pp.

Beentjes M. 2010. Toheroa survey of Oreti Beach, 2009, and review of historical surveys. New Zealand Fisheries Assessment Report 2010/6, ed. 40p.

Beentjes M., Boubée J., Jellyman J.D., Graynoth E. 2005. Non-fishing mortality of freshwater eels (Anguilla spp.). New Zealand Fisheries Assessment Report 2005/34. 38p.

Benn, L. 2009. Marine Protected Areas (MPA): Habitat Maps for Canterbury. Internal Report for the Canterbury Conservancy.

Booth J. 1979. North Cape - a 'nursery area' for the packhorse rock lobster, *Jasus verreauxi* (Deeapoda: Palinuridae). New Zealand journal of Marine & Freshwater Research (13): 521-528.

Caddy J.F. 2008. The importance of "Cover" in the life histories of demersal and benthic marine resources: A neglected issue in fisheries assessment and management. Bulletin of Marine Science (83): 7-52.

Chang C., Iizyuka Y., Tzeng W. 2004. Migratory environmental history of the grey mullet *Mugil cephalus* as revealed by otolith Sr:Ca ratios. Marine Ecology Progress Series. 269: 277-288.

Chiappone M., Sealey K.M.S. 2000. Marine reserve design criteria and measures of success: Lessons learned from the Exuma Cays Land and Sea Park, Bahamas. Bulletin of Marine Science (66): 691-705.

Clark MR (1999) Fisheries for orange roughy (Hoplostethus atlanticus) on seamounts in New Zealand. Oceanologica Acta 22: 593-602.

Clark MR, Rowden AA (2009) Effect of deepwater trawling on the macro-invertebrate assemblages of seamounts on the Chatham Rise, New Zealand. Deep Sea Research I 56: 1540–1554.

Clark, M.R.; Dunn, M.R. (2012). Spatial management of deep-sea seamount fisheries: balancing exploitation and habitat conservation. Environmental Conservation 39(2): . doi:10.1017/S0376892912000021

Costello, M., McCrea, M., Freiwald, A., Lundälv, T., Jonsson, L., Bett, B., van Weering, T., de Haas, H., Roberts, J., Allen, D., 2005. Role of cold-water Lophelia pertusa coral reefs as fish habitat in the NE Atlantic, in: Freiwald, A., JM, R. (Eds.), Cold-water Corals and Ecosystems. Springer-Verlag Berlin pp. pp 771-805.

Davidson, R., Richards, L., Duffy, C., Kerr, V., Freeman, D., D'Archino, R., Read, G., Abel, W., 2010. Location and biological attributes of biogenic habitats located on soft substrata in the Marlborough Sounds. , Prepared by Davidson Environmental Ltd. for Department of Conservation and Marlborough District Council. Survey and monitoring report no. 575.

Diaz R., Solan M., Valente R. 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. Journal of Environmental Management 73: 165–181.

Deep Water Group 2008. Operational Procedures: Hoki Fishery. 27p.

Dorenbosch M., Grol M., Christianen M., Nagelkerken I. van der Velde G. 2005. Indo-Pacific seagrass beds and mangroves contribute to fish density coral and diversity on adjacent reefs. Marine Ecology Progress Series. 302: 63-76.

Ellingsen, K., Hewitt, J., Thrush, S. 2007. Rare species, habitat diversity and functional redundancy in marine benthos. Journal of Sea Research 58: 291-301.

European Commission, 2003. Commission Regulation (EC) No 1475/2003 of 20 August 2003 on the protection of deep-water coral reefs from the effects of trawling in an area north west of Scotland. Official Journal L 211, 14-15.

Fosså, J., Mortensen, P., Furevik, D., 2002. The deep-water coral Lophelia pertusa in Norwegian waters: distribution and fisheries impacts. Hydrobiologia 471, 1-12.

Francis R., Hadfield M., Bradford-Grieve J., Renwick J., Sutton P. 2005. Environmental predictors of hoki year-class strengths: an update.

Francis, M., Morrison, M., Leathwick, J., Walsh, C., 2011. Predicting patterns of richness, occurrence and abundance of small fish in New Zealand estuaries. Marine and Freshwater Research 62, 1327-1341.

Francis, M., Lyon, W., Jones, E., Notman, P., Parkinson, D., Getzlaff, C., 2012. Rig nursery grounds in New Zealand: a review and survey, New Zealand Aquatic Environment and Biodiversity Report No. 95.

Gillanders B. Kingsford M. 1986. Elements in otoliths may elucidate the contribution of estuarine recruitment to sustaining coastal reef populations of a temperate reef fish. Marine Ecology Progress Series 141: 13 - 20.

Grange K., Tovey A., Hill A.F. 2003. The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay. 22 p.

Graynoth E., Francis R., Jellyman D. 2008. Factors influencing juvenile eel (Anguilla spp.) survival in lowland New Zealand streams New Zealand Journal of Marine and Freshwater Research [N. Z. J. Mar. Freshw. Res.]. Vol. 42, no. 2, pp. 153-172. Jun 2008. (42): 153-172.

Hall-Spencer J., Kelly J. Maggs C. 2008. Assessment of maerl beds in the OSPAR area and the development of a monitoring program. Department of Environment, Heritage and Local Government: Ireland.

Hamer P., Jenkins G., Gillanders B. 2005. Chemical tags in otoliths indicate the importance of local and distant settlement areas to populations of a temperate sparid, *Pagrus auratus*. Canadian Journal of Fisheries and Aquatic Sciences. 62: 623-630.

Haro A., Richkus W., Whalen K., Hoar A., Busch W.D., Lary S., Brush T., Dixon D. 2000. Population decline of the American eel: Implications for research and management. Fisheries (25): 7-16.

Helson J., Leslie S., Clement G., Wells R., Wood R. 2010. Private rights, public benefits: Industry-driven seabed protection. Marine Policy (34): 557-566.

Hewitt J.E., Thrush S.F., Halliday J., Duffy C. 2005. The importance of small-scale habitat structure for maintaining beta diversity. Ecology (86): 1619-1626.

Hiscock K., Tyler-Walters H. 2006. Assessing the seabed species and biotopes- the Marine Life Information Network (MarLIN). Hydrobiologica. 555: 309–320.

Hurst R., Bagley N., Anderson O., Francis M., Griggs L., Clark M., Paul L., Taylor P. 2000a. Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters.

Hurst R., Stevenson M., Bagley N., Griggs L., Morrison M., Francis M. 2000b. Areas of importance for spawning, pupping or egg-laying and juveniles of new Zealand coastal fish. . 56.

Inland Fisheries Service Tasmania 2009. Tasmanian Freshwater Eel Fishery: Application to the Department of the Environment, Water, Heritage and Arts for the re-assessment of the Tasmanian Freshwater Eel Fishery. 22.

Jelbart J., Ross P., Connolly R. 2007. Fish assemblages in seagrass beds are influenced by the proximity of mangrove forests. Marine Biology 150, 993–1002.

Jellyman D. 1994. The fishery for freshwater eels (*Anguilla* spp.) in New Zealand New Zealand Fisheries Assessment Research Document 94/14. 25p.

Kamenos, N., Moore, P., Hall-Spencer, J. 2004. Small-scale distribution of juvenile gadoids in shallow inshore waters; what role does maerl play? ICES Journal of Marine Science 61,422–429.

Keefer M., Peery C., Wright N., Daigle W., Caudill C., Clabough T., Griffith D., Zacharias M. 2008. Evaluating the NOAA Coastal and Marine Ecological Classification Standard in estuarine systems: A Columbia River Estuary case study. Estuarine, Coastal and Shelf Science. 78: 89–106.

Kerr L. 2008. Cause, consequence, and prevalence of spatial structure of white perch (Morone americana) populations in the Chesapeake Bay. Dissertation. University of Maryland, College Park, Maryland, USA.

Kerr L., Secor D. 2009. Bioenergetic trajectories underlying partial migration in Patuxent River (Chesapeake Bay) white perch Morone americana. Canadian Journal of Fisheries and Aquatic Sciences 66:602–612.

Kerr L.A., Cadrin S.X., Secor D.H. 2010. The role of spatial dynamics in the stability, resilience, and productivity of an estuarine fish population. Ecological Applications (20): 497-507.

Kerr V. 2010. Marine habitat map of Northland: mangawhai to Ahipara (vers 1).

Koenig C., Coleman F., Grimes C., FitzHugh G., Scanlon K., Gledhill C., Grace M. 2000. Protection of fish spawning habitat for the conservation of warm-temperate reef-fish fisheries of shelf-edge reefs of Florida. Bulletin of Marine Science (66): 593-616.

Leathwick J., Image K., Snelder T., Weatherhead M., Wild M. 2004. Definition and tests of the Marine Environment Classifications of New Zealand's Exclusive Economic Zone and the Hauraki Gulf. NIWA Client Report CHC2004-085. 64pp.

Leathwick J.R., Dey K., Julian K. 2006. Development of a demersal fish community classification for New Zealands Exclusive Economic Zone. . 38.

Leathwick J.R., Julian K. 2008. Updated conservation rankings for New Zealand's rivers and streams NIWA Report for Department of Conservation. 39.

Leathwick J., Rowden A., Nodder S., Gorman, R., Bardsley S., Pinkerton, M., Baird, S., Hadfield, M., Currie, K., Goh, A. 2012. Benthic optimised marine environment classification for New Zealand waters. Aquatic Environment and Biodiversity Report No. 89. 52pp.

Livingston M. 1990. Spawning hoki (Macruronus novaezelandiae Hector) concentrations in Cook Strait and off the east coast of the South Island, New Zealand, August-September 1987. New Zealand Journal of Marine and Freshwater Research (24):

Lundälv, T., Jonsson, L., 2003. Mapping of deep-water corals and fishery impacts in the north-east Skagerrak, using acoustical and ROV survey techniques. Proc 6th Underwater Sci Symp, Aberdeen, April 2003.

Madden C., Grossman D., Goodin K. 2005. Coastal and marine ecosystems of North America; framework for an ecological classification standard: Version II. NatureServe, Virginia, Arlington. 48 pp.

Morato, T., Hoyle, S.D., Allain, V. and Nicol, S.J. (2010a). Seamounts are hotspots of pelagic biodiversity in the open ocean. Proceedings of the National Academy of Science U S A, 107, 9707–9711. doi:10.1073/pnas.0910290107

Morato, T., Hoyle, S.D., Allain, V. and Nicol, S.J. (2010b). Tuna longline fishing around West and Central Pacific seamounts. PloS ONE 5(12): e14453. doi:10.1371/journal.pone.0014453

Morrisey, D., Swales A., Dittmann S., Morrison M., Lovelock, C., Beard, C. 2010. The ecology and management of temperate mangroves. Oceanography and Marine Biology 48: 43–160.

Morrison M., Jones E., Consalvey M., Berkenbusch K. 2008. Biogenic habitats and their value to New Zealand fisheries. Water & Atmosphere (16): 20-21.

Morrison M., Lowe M., Parsons D., Usmar N., McLeod I. 2009. A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. 100p.

Murawski S.A., Brown R., Lai H.L., Rago P.J., Hendrickson L. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: The Georges Bank experience. Bulletin of Marine Science (66): 775-798.

Nagelkerken I., Kleijnen S., Klop T., van den Brand, R., de la Moriniere, E., van der Velde G. 2001. Dependence of Caribbean reef fishes on mangroves and seagrass beds as nursery habitats: a comparison of fish faunas between bays with and without mangroves/seagrass beds. Marine Ecology Progress Series 214: 225–235.

North Pacific Fishery Management Council. 1998. Omnibus essential fish habitat amendments for groundfish in the Bering Sea, Aleutian Islands, and Gulf of Alaska, king and tanner crab in the Bering Sea and Aleutian Islands, Alaska scallop, and Alaska salmon fishery management plans. North Pacific Fishery Management Council , Alaska.

O'Driscoll R., Booth J., Bagley N., Anderson O., Griggs L., Stevenson M., Francis M. 2003. Areas of importance for spawning, pupping or egg-laying, and juveniles of New Zealand deepwater fish, pelagic fish, and invertebrates. NIWA Technical Report 119. 377.

O'Driscoll, R.L.; Clark, M.R. (2005). Quantifying the relative intensity of fishing on New Zealand seamounts. New Zealand Journal of Marine and Freshwater Research 39: 839–850.

Parsons D., Morrison M., McKenzie J., Hartill, B, Bian R., Francis RICC (2011) A fisheries perspective of behavioural variability: differences in movement behavior and extraction rate of an exploited sparid, snapper (Pagrus auratus). Canadian Journal of Fisheries and Aquatic Sciences. 68: 632-642.

Roberts C.M. 2000. Selecting marine reserve locations: Optimality versus opportunism. Bulletin of Marine Science (66): 581-592.

Rosenberg A., Bigford T., Leathery S., Hill R., Bickers K. 2000. Ecosystem approach to fishery management through essential fish habitat. Bulletin of Marine Science (66): 535-542.

Ross S., Moser M. 1995. Life-history of juvenile gag, Mycteroperca-microlepsis, in North-Carolina estuaries. Bulletin of Marine Science. 56; 222-237.

Schumacher J.D., Kendall A.W. 1991. Some interactions between young walleye Pollock and their environment in the western gulf of Alaska 40p.

Schwarz A.-M., Morrison M., Hawes I., Halliday J. 2006. Physical and biological characteristics of a rare marine habitat: subtidal seagrass beds of offshore islands. 39.

Thrush S.F., Gray J.S., Hewitt J.E., Ugland K.I. 2006. Predicting the effects of habitat homogenization on marine biodiversity. Ecological Applications (16): 1636-1642.

Tracey, D.M., Rowden, A.A., Mackay, K.A., Compton, T (2011) Habitat-forming cold-water corals show affinity for seamounts in the New Zealand region. Marine Ecology Progress Series 430: 1–22.

Turner G.E., Boesch D. 1987. Aquatic animal production and wetland relationships: insights gleaned following wetland loss or gain. In: Hooks D. (Ed.) Ecology and management of wetlands. Croon Helms, Ltd., Beckenham, Kent, U.K. 25-39.

Turner S., Schwarz A.-M. 2006. Management and conservation of seagrass in New Zealand: an introduction. (264): 90.

Vooren C. 1975. Nursery grounds of tarakihi (Teleostei: Cheilodactylidae) around New Zealand. New Zealand Journal of Marine and Freshwater Research (9): 121-158.

Warner R.R., Swearer S.E., Caselle J.E. 2000. Larval accumulation and retention: Implications for the design of marine reserves and essential fish habitat. Bulletin of Marine Science (66): 821-830.

Western Pacific Regional Fishery Management Council 1998. Magnuson-Stevens Act definitions and required provisions. Western Pacific Regional Fishery Management Council, Hawaii.

10. Land-based effects on fisheries, aquaculture and supporting biodiversity

Scope of chapter	This chapter outlines the main known threats from land-based activities to fisheries, aquaculture and supporting biodiversity. It also describes the present status and trends in land-based impacts.
Area	All of the New Zealand freshwater, EEZ and territorial sea.
Focal localities	Freshwater habitats and areas closest to the coast are likely to be most impacted; this will be exacerbated in areas with low water movement. Anthropogenically increased sediment run-off is particularly high from the Waiapu and Waipaoa river catchments on the east coast of the North Island. Areas of intense urbanisation or agricultural use of catchments are also likely to be impacted by bacteria, viruses, heavy metals and nutrients.
Key issues	Habitat modification, sedimentation, aquaculture, shellfish, terrestrial land-use change (particularly for urbanisation, forestry or agriculture) water quality and quantity, contamination, consequences to seafood production of increased pollutants, freshwater management and demand.
Emerging issues	Impacts on habitats of particular significance to fisheries management (HPSFM), linkages through rainfall patterns to climate change, shellfish bed closures, habitat remediation, domestic animal diseases in protected marine species, proposed aquaculture expansion, water abstraction impacts.
MPI Research (current)	Habitats of particular significance for fisheries management: Kaipara Harbour (ENV2009/07), Toheroa abundance (TOH2007/03), Biogenic habitats as areas of particular significance for fisheries management (HAB2007/01), Research on Biogenic Habitat-Forming Biota and their functional role in maintaining Biodiversity in the Inshore Region, 5-150m depths (ZBD2008/01 – this is also part-funded by Oceans Survey 2020, NIWA and MBIE).
NZ Government Research (current)	Ministry of Business, Innovation and Employment (MBIE) funded programs: (After the outfall: recovery from eutrophication in degraded New Zealand estuaries (UOCX0902). NIWA Core funding in two areas. Firstly, The ’Managing marine stressors’ area under the ’Coasts and Oceans’ centre, specifically the programme ’Managing marine resources’ and the project ’Measuring mapping and conserving (C01X0505)’. Secondly, in the ’Fisheries’ Centre programme 3 which deals with ecosytem-based management approaches in conjunction with the ’Coasts and Oceans’ centre.
Links to 2030 objectives	Objective 8: Improve RMA fisheries interface. Objective 4: Support aquaculture development
Related chapters/issues	Habitats of particular significance for fisheries management (HPSFM), marine environmental monitoring.

10.1. *Context*

It has been acknowledged for some time now that land-based activities can have important effects on seafood production. The main threats to the quality and use of the world’s oceans are (GESAMP 2001):

- alteration and destruction of habitats and ecosystems;
- effects of sewage on human health;

- widespread and increased eutrophication;
- decline of fish stocks and other renewable resources; and
- changes in sediment flows due to hydrological changes

. Coastal development is projected to impact 91% of all inhabited coasts by 2050 and will contribute to more than 80% of all marine pollution (Nellemann *et al.* 2008).

Aquaculture and land-based activities that may have impacts on seafood production are primarily regulated under the Resource Management Act 1991 (and subsequent amendments). Fisheries are controlled under the Fisheries Act 1996. Fisheries 2030 is a long-term policy strategy and direction paper of the Ministry for Primary Industries. It was released in 2009 and states that improving the Fisheries/Resource Management Act interface is a priority (objective 8). Strategic actions to achieve this priority are listed as:

8.1 Improve fisheries sector input to processes that manage RMA-controlled effects on the marine and freshwater environment.
8.2 Promote the development and use of RMA national policy statements, environmental standards, and regional coastal and freshwater plans

The Government's 'Fresh Start for Freshwater Programme[26]' (lead by MfE and MPI) is addressing a range of issues through a water reform strategy that includes governance, setting objectives and limits, managing within limits (quality and quantity) and that better reflects Maori/Iwi rights and interests in water management. The Coastal Policy Statement (2010) also has relevance to matters of fisheries interest, e.g. Policy 20(1) (*paraphrased*) controls the use of vehicles on beaches where (b) harm to shellfish beds may result. MPI also works with other agencies, principally DOC, MfE and regional councils and through the Natural Resource Cluster to influence these processes to ensure consideration of land-based impacts upon seafood production.

Land-based effects on seafood production and supporting biodiversity in this context are defined as resulting either from the inputs of contaminants from terrestrial sources or through engineering structures (e.g., breakwaters, causeways, bridges) that change the nature and characteristics of coastal habitats and modify hydrodynamics. The major route for entry of land-based contaminants into the marine environment is associated with freshwater flows (rivers, streams, direct runoff and ground water), although contaminants may enter the marine environment via direct inputs (e.g., landslides) or atmospheric transport processes.

The most important land-based effect in New Zealand is arguably increased sediment deposition around our coasts (Morrison *et al.* 2009). This deposition has been accelerated due to increased erosion from land-use, which causes gully and channel erosion and landslides (Glade 2003). Inputs of sediments to our coastal zone, although naturally high in places due to our high rainfall and rates of tectonic uplift (Carter 1975), have been accelerated by human activities (Goff 1997). Sediment inputs are now high by world standards and make up ~1% of the estimated global detrital input to the oceans (Carter *et al.* 1996). By contrast New Zealand represents only ~ 0.3% of the land area that drains into the oceans (Griffiths and Glasby 1985, Milliman and Syvitski 1992).

Different land use effects act over different scales; for example localised effects act on small streams and adjacent estuarine habitats, large scale effects extend to coastal embayments and shelf ecosystems. Associated risks will vary according to location and depend on the relevant ecosystem services (e.g. high value commercial fishery stocks) and their perceived sensitivities. The risk from stormwater pollutants will be more important near urban areas and the effects of nutrient enrichment will be more important near intensively farmed rural areas.

[26] http://www.mfe.govt.nz/issues/water/freshwater/fresh-start-for-fresh-water/

The risk from land-based impacts for seafood production is that they will limit the productivity of a stock or stocks. For example, the bryozoan beds around Separation Point in Golden Bay, were protected from fishing, amongst other reasons, due to their perceived role as nursery grounds for a variety of coastal fish species in 1980 (Grange *et al.* 2003). Recent work has suggested the main threat to these bryozoans is now sedimentation from the Motueka River, which may inhibit recovery of any damaged bryozoans (Grange *et al.* 2003, Morrison *et al.* 2009). Any declines in this bryozoan bed and associated ecological communities could also affect the productivity of adjacent fishery stocks.

The New Zealand aquaculture industry has an objective of developing into a billion dollar industry by 2025 (Aquaculture New Zealand 2012). Government supports well-planned and sustainable aquaculture through its *Aquaculture Strategy* and *Five-year Plan.* One of the desired outcomes of actions by the New Zealand Government is to enable more space to be made available for aquaculture. This outcome is likely to heighten the potential for conflict between aquaculture proponents and those creating negative land-based effects.
MPI mainly manage in the marine environment, therefore this topic area will be dealt with first. MPI also manages the freshwater eel fishery; this will be dealt with latterly within relevant sections.

10.2. *Global understanding*

10.2.1. Land-based influences

The importance of different land-based influences differ regionally but the South Pacific Regional Environmental Programme (SPREP, which includes New Zealand) defines waste management and pollution control as one of its four strategic priorities for 2011-2015 (SPREP 2010). “

Influences, including land-based influences, seldom work in isolation; for example the development of farming and fishing over the last hundred years has meant that increased sediment and nutrient runoff has to some degree occurred simultaneously with increased fishing pressure. However, the impact of these influences has often been studied in isolation. In a review on coastal eutrophication, Cloern (2001) stated that “*Our view of the problem* [eutrophication] *is narrow because it continues to focus on one signal of change in the coastal zone, as though nutrient enrichment operates as an independent stressor; it does not reflect a broad ecosystem-scale view that considers nutrient enrichment in the context of all the other stressors that cause change in coastal ecosystems*”. These influences (in isolation or combination) can also cause indirect effects, such as decreasing species diversity which then lessens resistance to invasion by non-indigenous species or species with different life-history strategies (Balata *et al.* 2007, Kneitel and Perrault 2006, Piola and Johnston 2008). Studies that research a realistic mix of influences are rare.

Sediment deposition can be an important influence, particularly in areas of high rainfall, tectonic uplift, and forest clearances, or areas where these activities coincide. Sediments are known to erode from the land at an increased rate in response to human use, for example, estimates from a largely deforested tropical highland suggest erosion rates 10-100 times faster than pre-clearance rates (Hewawasam *et al.* 2003). Increased sediment either deposited on the seafloor or suspended in the water column can negatively impact upon invertebrates in a number of ways including: burial, scour, inhibiting settlement, decreasing filter-feeding efficiency and decreasing light penetration, generally leading to less diverse communities, with a decrease in suspension feeders (Thrush *et al.* 2004). These impacts can affect the structure, composition and dynamics of benthic communities (Airoldi 2003, Thrush *et al.* 2004). Effects of this increased sediment movement and deposition on finfish are mostly known from freshwater fish and can range from behavioural (such as decreased feeding rates) to sublethal (e.g., gill tissue disruption) and lethal as well as having effects on habitat important to fishes (Morrison *et al.* 2009). These effects differ by species and life-stages and are dependant upon factors that include the duration, frequency and magnitude of exposure, temperature, and other environmental variables (Servizi and Martens 1992).

Increased nutrient addition to the aquatic environment can initially increase production, but with increasing nutrients there is an increasing likelihood of harmful algal blooms and cascades of effects damaging to most communities above the level of the plankton (Kennish 2002; Heisler *et al.* 2008). This excess of nutrients is termed eutrophication. Eutrophication can stimulate phytoplankton growth which can decrease the light availability and subsequently lead to losses in benthic production from seagrass, microalgae or macroalgae and their associated animal communities. Algal blooms then die and their decay depletes oxygen and blankets the seafloor. The lack of oxygen in the bed and water column can lead to losses of finfish and benthic communities. These effects are likely to be location specific and are influenced by a number of factors including: water transparency, distribution of vascular plants and biomass of macroalgae, sediment biogeochemistry and nutrient cycling, nutrient ratios and their regulation of phytoplankton community composition, frequency of toxic/harmful algal blooms, habitat quality for metazoans, reproduction/growth/survival of pelagic and benthic invertebrates, and subtle changes such as shifts in the seasonality of ecosystems (Cloern 2001). These effects of eutrophication abound in the literature, for example, the formation of dead (or anoxic) zones is exacerbated by eutrophication, although oceanographic conditions also play a key role (Diaz and Rosenberg 2008). Dead zones have now been reported from more than 400 systems, affecting a total area of more than 245,000 square kilometres (Diaz and Rosenberg 2008). This includes anoxic events from New Zealand in coastal north-eastern New Zealand and Stewart Island (Taylor *et al.* 1985, Morrissey 2000).

Other pollutants such as heavy metals and organic chemicals can have severe effects, but are more localised in extent than sediment or nutrient pollution (Castro and Huber 2003, Kennish 2002). Fortunately the concentration of these pollutants in most New Zealand aquatic environments is relatively low, with a few known exceptions. Examples of this include naturally elevated levels of arsenic in Northland[27], Cadmium levels in Foveaux Strait oysters (Frew *et al.* 1996) and levels of Nickel and chromium within the Motueka river plume in Tasman Bay (Forrest *et al.* 2007). The Cadmium levels have caused market access issues for Foveaux Strait Oysters. Some anthropogenically generated pollutants such as copper, lead, zinc and PCBs are high in localised hotspots within urban watersheds. In the Auckland region these hotspots tend to be in muddy estuarine sites and tidal creeks that receive runoff from older urban catchments[28]. There is a lack of knowledge on the impacts of these pollutants upon fisheries.

Climate change is likely to interact with the effect of land-based impacts as the main delivery of land-based influences is through rainfall and subsequent freshwater flows. Global climate change projections include changes in the amount and regional distribution of rainfall over New Zealand (IPCC 2007). More regional predictions include increasing frequency of heavy rainfall events over New Zealand (Whetton *et al.* 1996). This is likely to exacerbate the impact of some land-based influences as delivery peaks at times of high rainfall, e.g. sediment delivery (Morrison *et al.* 2009).

Physical alterations of the coast are generally, but not exclusively (i.e. wetland reclamation for agriculture), concentrated around urban areas and can have a number of consequences on the marine environment (Bulleri and Chapman 2010). Changes in diversity, habitat fragmentation or loss and increased invasion susceptibility have all been identified as consequences of physical alteration. The effects of physical alterations upon fisheries remain largely unquantified; however the habitat loss or alteration portion of physical alterations will be dealt with under the habitats of particular significance for fisheries management (HPSFM) section.

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[27] Accessible on the www.os2020.org.nz website.

[28] Available from the State of the Auckland Region report 2010, Chapter 4.4 Marine, at http://www.arc.govt.nz/albany/index.cfm?FD6A3403-145E-173C-986A-A0E3C199B8C5

An area of emerging interest internationally is infectious diseases from land-based animals affecting marine populations. Perhaps the most well-known example of this is the canine distemper outbreak in Caspian seals that cause a mass mortality in the Caspian sea in 2000 (Kennedy *et al.* 2000)

10.2.2. Habitat restoration

Habitat restoration or rehabilitation has been the subject of much recent research. Habitat restoration or rehabilitation rarely, if ever, replaces what was lost and is most applicable in estuarine or enclosed coastal areas as opposed to exposed coastal or open ocean habitats (Elliott *et al.* 2007). Connectivity of populations is a key consideration when evaluating the effectiveness of any marine restoration or rehabilitation (Lipcius *et al.* 2008). In the marine area, seagrass replanting methodologies are being developed to ensure the best survival success (Bell *et al.* 2008) and artificial reefs can improve fisheries catches, although whether artificial reefs boost population numbers or merely attract fish is unclear (Seaman 2007). In addition, The incorporation of habitat elements in engineering structures, e.g., artificial rockpools in seawalls, shows promise in terms of ameliorating impacts of physical alterations (Bulleri 2006). Spatial approaches to managing land-use impacts, such as marine reserves, will be covered under the section about HPSFM.

Freshwater rehabilitation has been reviewed by Roni *et al.* (2008). Habitat reconnection, floodplain rehabilitation and instream habitat improvement are all suggested to result in improved habitat and local fish abundances. Riparian rehabilitation, sediment reduction, dam removal, and restoration of natural flood regimes have shown promise for restoring natural processes that create and maintain habitats, but there is a lack of long-term studies to gauge their success. Wild eel fisheries in America and Europe have declined over time (Allen *et al.* 2006, Atlantic States Marine Fisheries Commission 2000, Haro *et al.* 2000). Declines in wild eel fisheries have been linked to a number of factors including: barriers to migration; hydro turbine mortality; and habitat loss or alteration. Information to quantitatively assess these linkages is however often lacking (Haro *et al.* 2000).

10.3. *State of knowledge in New Zealand*

Land-based effects will be most pronounced closest to the land, therefore it is freshwater, estuarine, coastal, middle depths and deepwater fisheries, in decreasing order, that will be most affected. The scale of land-use effects will, however, differ depending upon the particular influence. The most localised of these are likely to be direct physical impacts; for example, the replacement of natural shorelines with seawalls; although even direct physical impacts can have larger scale impacts, such as affecting sediment transport and subsequently beach erosion, or contributing to cumulative effects upon ecosystem responses. Point-source discharges are likely to have a variable scale of influence, and this influence is likely to increase where a number of point-sources discharge, particularly when this occurs into an embayed, low-current environment. An example of this is the multiple stormwater discharges into the Waitemata harbour in Auckland (Hayward *et al.* 2006). The largest influence can be from diffuse-source discharges such as nutrients or sediment (Kennish 2002). For example, the influence of diffuse-source materials from the Motueka river catchment in Golden Bay on subtidal sediments and assemblages and shellfish quality can extend up to tens of kilometres offshore (Tuckey *et al.* 2006; Forrest *et al.* 2007), with even a moderate storm event extending a plume greater than 6km offshore (Cornelisen *et al.* 2011). Terrestrial influences on New Zealand’s marine environment can, at times be detected by satellites from differences in ocean colour and turbidity extending many kilometres offshore from river mouths (Gibbs *et al.* 2006).

All coastal areas are unlikely to suffer from land-based impacts in the same way. The quantities of pollutants or structures differ spatially. Stormwater pollutants, seawalls and jetties are more likely to be concentrated around urban areas. Nutrient inputs are likely to be concentrated either around sewage outlets or associated with areas of intensive agriculture or horticulture. Sediment production has been mapped around the country and is greatest around the west coast of the South Island and the East coast of the North Island (Griffiths and Glasby 1985, Hicks and Shankar 2003, Hicks *et al.* 2011). Notably the catchments where improved land management may result in the biggest changes to sediment delivery to coastal environments are likely to be the Waiapu and Waipaoa river catchments on the East coast of the North Island. In addition to this, the sensitivity of receiving environments is also likely to differ; this will be covered in subsequent sections.

A MPI funded survey of scientific experts (MacDiarmid *et al.* 2012) addressed the vulnerability to a number of threats of marine habitat types within the New Zealand's Territorial Sea and Exclusive Economic Zone (EEZ). Each vulnerability score was based on an assessment of five factors including the spatial scale, frequency and functional impact of the threat in the given habitat as well as the susceptibility of the habitat to the threat and the recovery time of the habitat following disturbance from that threat. The study found that the number of threats and their severity were generally considered to decrease with depth, particularly below 50m. Reef, sand, and mud habitats in harbours and estuaries and along sheltered and exposed coasts were considered to be the most highly threatened habitats. The study also reported that over half of the twenty-six top threats fully, or in part, stemmed from human activities external to the marine environment itself. The top six threats in order were:

1. ocean acidification,
2. rising sea temperatures resulting from global climate change,

3rd equal bottom trawling fishing,

3rd equal increased sediment loadings from river inputs

5th equal change in currents from climate change

5th equal increased storminess from climate change

The reader is guided to MacDiarmid *et al.* (2012) for more detail including tables of threats-by-habitat and habitats-by-threat. Climate change and ocean acidification, although they can be considered land-based effects, are covered under the Chapters in this document called "New Zealand Regional climate and oceanic setting" and "Biodiversity".

The protozoan *Toxoplasma gondii* has been identified as the cause of death for 7 of 28 Hector's and Maui's dolphins examined since 2007 (W. Roe, Massey University, unpubl. data, 31 July 2012). Land-based runoff containing cat faeces is believed to be the means by which *Toxoplasma gondii* enters the marine environment (Hill & Dubey 2002). A Hectors dolphin has also tested positive for *Brucella abortus* (or a similar organism) a pathogen of terrestrial mammals that can cause late pregnancy abortion, and has been seen in a range of cetacean species elsewhere[29].

10.3.1. Completed research

A MPI funded project (IPA2007/07) reviewed the impacts of land based influences on coastal biodiversity and fisheries (Morrison *et al.* 2009). This review used a number of lines of evidence to conclude that in this context, sedimentation is probably New Zealand's most important pollutant. The negative impacts of sediment include decreasing efficiency of filter-feeding shellfish (such as cockles, pipi, and scallops), reduced settlement success and survival of larval and juvenile phases (e.g., paua, kina), and reductions in the foraging abilities of finfish (e.g., juvenile snapper). Indirect effects include the modification or loss of important nursery habitats, particularly biogenic habitats (green-lipped and horse mussel beds, seagrass meadows, bryozoan and tubeworm mounds, sponge gardens,

[29] http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-tmp-discussion-document-full.pdf

kelps/seaweeds, and a range of other structurally complex species). Inshore filter-feeding bivalves and biogenic habitats were identified as the most likely to be adversely affected by sedimentation. Eutrophication was also identified as a potential threat from experience overseas.

Marine restoration studies published in New Zealand have focused on the New Zealand cockle *Austrovenus stutchburyi*. The first of these studies identified a tagging methodology to aid relocation of transplanted individuals (Stewart and Creese 1998). Subsequent studies stressed the use of adults in restoration and the importance of site selection, either from theoretical or modelling viewpoints (Lundquist *et al.* 2009, Marsden and Adkins 2009). Detailed restoration methodology has been investigated in Whangarei Harbour and recommends replanting adults at densities between 222 and 832 m^{-2} (Cummings *et al.* 2007).

Multiple influences in areas relevant to seafood production in New Zealand have been addressed by three studies. A field experiment near Auckland showed greater effects of three heavy metals (Copper, lead and Zinc) in combination compared to isolation on infaunal colonisation of intertidal estuarine sediments (Fukunaga *et al.* 2010). A survey approach looking at the interaction of sediment grain size, organic content and heavy metal contamination upon densities of 46 macrofaunal taxa across the Auckland region also showed a predominance of multiplicative effects (Thrush *et al.* 2008). Although influences can work in unexpected directions; as in a study on large suspension feeding bivalves off estuary mouths where the anticipated negative impacts from sediment were not observed and these species benefited from food resources generated from those estuaries (Thrush *et al.* In Press).

Toheroa populations are currently closed to all but customary harvesting but have failed to recover to former population levels even though periodic (and sometimes substantial) pulses in young recruits have been detected in both Northland and Southland (Beentjes 2010, Morrison and Parkinson 2008). Current thinking suggests a mix of influences are probably responsible for these declines including over-harvesting, land-use changes leading to changes in freshwater seeps on the beaches and vehicle traffic (Morrison *et al.* 2009). A number of discrete pieces of research have been completed in this area. A review of the wider impact of vehicles on beaches and sandy dunes has been completed, and suggested more research was needed on the impacts of vehicle traffic on the intertidal (Stephenson 1999). A four day study over a fishing contest on 90 mile beach showed the potential of traffic to produce immediate mortalities of juvenile toheroa, but the temporal importance of this could not be gauged (Hooker and Redfearn 1998). Mortalities of toheroa from the Burt Munro Classic motorcycle race on Oreti beach have been quantified and recommendations made for how to minimise these, but again the importance of vehicle traffic for toheroa survival over longer time periods was unclear (Moller *et al.* 2009).

The effects of large-scale habitat loss and modification on eels in New Zealand are clearly significant, but difficult to quantify (Beentjes *et al.* 2005). Significant non-fisheries mortality of New Zealand freshwater longfin and shortfin eels are caused by mechanical clearance of drainage channels, and damage by hydro-electric turbines and flood control pumping. Eels prefer habitat that offers cover and in modified drains aquatic weed provides both daytime cover and nighttime foraging areas. Loss of weed and natural debris can thus result in significant displacement of eels to other areas. In addition, wetlands drainage has resulted in greatly reduced available habitat for eels, particularly shortfins which prefer slower-flowing coastal habitats such as lagoons, estuaries, and lower reaches of rims. Water abstraction is one of a number of information requirements identified in this paper to better define the effects on eel populations.

Rhodolith beds have been surveyed in the Bay of Islands and high diversity reported even in areas of abundant fine sediments (Nelson *et al.* 2012). It is unclear if the increasing sedimentation occurring in the Te Rawhiti Reach is negatively impacting rhodoliths and whether this atypical rhodolith bed (i.e., with abundant fine sediments) is at risk if current sedimentation and mobilisation rates continue.

A number of Integrated Catchment Management (ICM) projects are underway in New Zealand. These take a holistic view to land management incorporating aquatic effects; this approach could help restore water quality of both fresh and coastal waters. An overview of these projects is given in a Ministry for the Environment Report on integrated catchment management (Environmental Communications Limited 2010). Many of these projects employ restoration techniques such as riparian planting, but few assessments of the effectiveness of riparian planting exist. One assessment of the effect of nine riparian zone planting schemes in the North Island on water quality, physical and ecological indicators concluded that riparian planting could improve stream quality; in particular rapid improvements were seen in terms of visual clarity and channel stability (Parkyn *et al.* 2003). Nutrient and faecal contamination results were more variable. Improvement in macroinvertebrate communities did not occur in most streams and the three factors needed for these were canopy closure (which decreased stream temperature), long lengths of riparian planting and protection of headwater tributaries. A modelling study also demonstrated the long time lag needed to grow large trees which then provide wood debris to structure channels which achieves the best stream rehabilitation results (Davies-Colley *et al.* 2009). Although some of these studies extend into the marine realm (at least in terms of monitoring) it is difficult to gauge the impact of these activities upon fisheries or aquaculture, particularly on wider scales because ICM studies have been localised at small scales.

The review of land based effects (Morrison *et al.* 2009) identified knowledge gaps and made suggestions for more relevant research on these influences:

- identification of fisheries species/habitat associations for different life stages, including consideration of how changing habitat landscapes may change fisheries production;
- better knowledge of connectivity between habitats and ecosystems at large spatial scales;
- the role of river plumes;
- the effects of land-based influences both directly on fished species, and indirectly through impacts on nursery habitats;
- a better spatially-based understanding, mapping and synthesis of the integrated impacts of land-based and marine-based influences on coastal marine ecosystems.

The locations where addressing land-based impacts is likely to result in a lowering in risk to seafood production or increased seafood production, excluding those already mentioned, are undefined.

10.3.2. Current research

A number of ongoing research projects exist that will improve the knowledge of land-based impacts upon seafood production. Project ENV2009/07 investigates habitats of particular significance for fisheries management within the Kaipara Harbour and one objective is to assess fishing and land-based threats to these habitats. Current research is investigating the impact of a range of influences upon toheroa at Ninety-Mile Beach (project TOH2007/03). Environmental factors, including land-based impacts (particularly vehicle use and changing land-use patterns) are implicated in poor recovery of this population since the closure of this commercial and recreational fishery in the 1960s. A MPI biodiversity project also has components that address land-based effects; the threats to biogenic habitats are addressed in project ZBD2008/01.

Research is also ongoing on land-use effects at a national scale. A national scale threat analysis is also being carried out for biogenic habitats, given their likely importance for fisheries management (project HAB2007/01). A Ministry of Business, Innovation and Employment (MBIE) funded project [30] of particular relevance is (project number and lead agencies in brackets): Nitrogen reduction and benthic recovery (UOCX0902, University of Canterbury). This research aims to determine the trajectories and thresholds of coastal ecosystem recovery following removal of excessive nutrient

[30] http://www.msi.govt.nz/update-me/who-got-funded/

loading (called "eutrophication") and earthquake impacts. This will be achieved by monitoring the effects of diverting all of Christchurch's treated wastewater discharge from the eutrophied Avon-Heathcote (Ihutai) Estuary and the subsequent earthquake induced disturbances to this diversion.

Although not current research, the Department of Conservations suggested research priorities in the *"Review of the Maui's dolphin Threat management plan: Consultation paper"* include objectives to determine the presence, pathways and possible mitigation of the threat from *Toxoplasmosis gondii*[31].

10.4. *Indicators and trends*

A national view of the impacts of land-based influences upon seafood production does not exist; this could be facilitated by better coordination and planning of the many disparate marine monitoring programmes running around the country. Monitoring of marine water quality and associated communities is carried out through a variety of organisations, including, universities, regional councils and aquaculture or shellfisheries operations. Regional council monitoring of water quality and associated biological communities is often reported through web sites such as the Auckland Regional Council environmental monitoring data which is available on the internet[32] or summary reports such as the Hauraki Gulf state of the Environment 2011 report[33] Water quality and associated communities may also be monitored for a regional council as part of a consent application or as a stipulation for a particular marine development. The data from aquaculture and shellfisheries water quality monitoring is not generally available. Improved coordination and planning of marine monitoring has been achieved in some places, e.g., the United Kingdom[34] The Marine Environmental Monitoring Programme (ZBD2010-42), is a step towards this goal, more information is available on this project in the *Biodiversity* chapter of this document. Possible national scale proxies for coastal faecal contamination may exist after collating information from sanitation area monitoring for shellfish harvesting or shellfish harvesting closure information.

Marine water quality indicators are available nationally from 407 coastal bathing beaches which have been monitored for human health issues, rather than environmental purposes, over the last six years[35]. No temporal trends were detectable in this relatively short time period, however changes in sites monitored over this time may have confounded this analysis. Over the 2007-8 and 2008-9 summers, 79% of the swimming sites met the guidelines for contact recreation almost all the time. At least 95% of the samples at these sites had safe *Enterococci* levels (which is an indicator of human and animal sewage). Two percent of the sites (located within the Manukau harbour and on the West coast of Auckland), breached the guidelines more than 25% of the time. In general, the most polluted sites were embayed locations with poor natural flushing.

The Ministry for the Environment (MfE) also reports on freshwater quality. River water quality indicators that have been assessed have direct relevance to the eel, and other freshwater fisheries, and this water will flow through estuaries and enter the marine environment. The National River Water Quality Network (NRWQN) has national coverage, and has been running for over 20 years and has recently reported upon the following 8 variables: temperature, dissolved oxygen, visual clarity, dissolved reactive and total phosphorous, and ammoniacal, oxidised and total nitrogen (Ballantine and

[31] http://www.doc.govt.nz/Documents/conservation/native-animals/marine-mammals/maui-tmp/mauis-tmp-discussion-document-full.pdf
[32] http://maps.auckland.govt.nz/aucklandregionviewer/?widgets=HYDROTEL
[33] http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Coastal%20and%20marine/hgfstateoftheenvreport2011.pdf
[34] http://www.cefas.co.uk/data/marine-monitoring/national-marine-monitoring-programme-(nmmp).aspx
[35] http://www.mfe.govt.nz/environmental-reporting/freshwater/recreational/snapshot/coastal.html#results

Davies-Colley 2009). Dissolved oxygen showed few meaningful trends and the ammoniacal nitrogen data suffered from a processing artefact. An upward, although not significant trend in temperature and an improvement of water clarity were seen at the national scale. However, a negative correlation was seen between water clarity and percent of catchment in pasture, which suggests any expansion of pasture lands may have impacts on clarity. Strong increasing trends over time were seen in oxidised nitrogen, total nitrogen, total phosphorous and dissolved reactive phosphorous. These latter trends all signify deteriorating water quality and are mainly attributable to increased diffuse-source pollution from the expansion and intensification of pastoral agriculture.

Total Nitrogen and Phosphorous loads to the coast in New Zealand have been modelled and were estimated at 167,300 and 63,100 t yr^{-1}, respectively (Elliot *et al.* 2005)[36]. The main sources of Nitrogen and Phosphorous were from pastoralism (70%) and erosion (53%), respectively. The dairy herd in New Zealand has approximately doubled (increased 211%) since 1981 (whilst other grazer numbers have been relatively stable or declining)[9]. The amount of Urea and Superphosphate (New Zealand's most common nitrogen and phosphorous fertiliser) have increased 27.7 and 1.6 fold, respectively over the same period[37]. The use of Urea is currently around 100 $kg.ha^{-1}$ for dairying and ~10 $kg.ha^{-1}$ for sheep and beef farms (MPI 2012). The area in dairy farming is ~ 2 million hectares compared to 3.6 million hectares for sheep and 2 million hectares in beef farming (MPI 2012). Therefore Urea use in New Zealand is dominated by the dairy industry. These statistics provide strong circumstantial evidence that the expansion in dairying is primarily responsible for these declines in water quality from agricultural sources.

High faecal coliform counts (primarily from mammal or bird faeces) can impact upon the value gained from shellfish fisheries and aquaculture. Area closures to commercial harvesting usually depend on an areas rainfall/runoff relationship and areas closer to significant farming areas or urban concentrations are likely to be closed more frequently, due to high faecal coliform counts, than areas where the catchment is unfarmed or not heavily populated, e.g. Inner Pelorus sound is likely to be closed more frequently than outer Pelorus Sound (Marlborough Sounds)[38]. For coastal areas of the Marlborough Sounds, the Coromandel Peninsula and Northland closures can range from a few days to over 50 percent of the time in a given year[39]. Certain fisheries may in practice be limited by the amount of time where water quality is sufficient to allow harvesting, e.g. the cockle fishery in COC1A (Snake bank in Whangarei harbour) was closed for 101, 96, 167, 96 and 117 days for the 2006-7, 2007-8, 2008-9, 2009-10 and 2010-11 fishing years, respectively due to high faecal coliform counts from sewage spills or runoff[40]. Models also now exist that allow real-time prediction of E. coli pulses associated with storm events, e.g. Wilkinson *et al.* 2011, which may help harvesters to better cope with water quality issues.

10.5. *References*

Airoldi L. 2003. The effects of sedimentation on rocky coast assemblages. In: Oceanography and Marine Biology. 161-236.

Allen M., Rosell R., Evans D. 2006. Predicting catches for the Lough Neagh (Northern Ireland) eel fishery based on stock inputs, effort and environmental variables. Fisheries Management and Ecology (13): 251-260.

Atlantic States Marine Fisheries Commission 2000. Interstate Fishery Management Plan for American Eel. Fishery Management Report No. 36 of the Atlantic States Marine Fisheries Commission. 93p.

Balata D., Piazzi L., Cinelli F. 2007. Increase of sedimentation in a subtidal system: Effects on the structure and diversity of macroalgal assemblages. Journal of Experimental Marine Biology and Ecology (351): 73-82.

Ballantine D., Davies-Colley R. 2009. Water quality trends at National River Water Quality Network sites for 1989–2007. Prepared for Ministry for the Environment, NIWA Client Report: HAM2009-026. 43p.

Beentjes M., Boubée J., Jellyman J.D., Graynoth E. 2005. Non-fishing mortality of freshwater eels (*Anguilla* spp.). New Zealand Fisheries Assessment Report 2005/34. 38p.

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[36] This is an underestimate because streams with catchments less than $10km^2$ were excluded from this calculation.

[8] http://www.stats.govt.nz/infoshare

[10] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.

[11] Pers. Comms. Brian Roughan, New Zealand Food Safety Authority.

[12] Statistics supplied by New Zealand Food Safety Authority in Whangarei.

Beentjes M. 2010. Toheroa survey of Oreti Beach, 2009, and review of historical surveys. 40p.
Bell S.S., Tewfik A., Hall M.O., Fonseca M.S. 2008. Evaluation of seagrass planting and monitoring techniques: Implications for assessing restoration success and habitat equivalency. Restoration Ecology (16): 407-416.
Bulleri F. 2006. Is it time for urban ecology to include the marine realm? Trends in Ecology & Evolution (21): 658-659.
Bulleri F., Chapman M. 2010. The introduction of coastal infrastructure as a driver of change in marine environments. Journal of Applied Ecology (47): 26-35.
Carter L. 1975. Sedimentation on the continental terrace around New Zealand: A Review. Marine Geology (19): 209-237.
Carter L., Carter R., McCave I., Gamble J. 1996. Regional sediment recycling in the abyssal Southwest Pacific Ocean. Geology (24): 735-738.
Castro P., Huber M. 2003. Marine Biology. (Vol) 4. New York, McGraw Hill Higher Education.
Cloern J. 2001. Our evolving conceptual model of the coastal eutrophication problem Marine Ecology Progress Series (210): 223-253.
Cornelisen, C., Gillespie, P., Kirs, M., Young, R., Forrest, R., Barter, P., Knight, B., Harwood, V., 2011. Motueka River plume facilitates transport of ruminant faecal contaminants into shellfish growing waters, Tasman Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research 45, 477-495.
Cummings V., Hewitt J., Halliday J., Mackay G. 2007. Optimizing the success of *Austrovenus stutchburyi* restoration: preliminary investigations in a new zealand estuary. Journal of Shellfish Research (26): 89-100.
Davies-Colley R.J., Meleason M.A., Hall G.M.J., Rutherford J.C. 2009. Modelling the time course of shade, temperature, and wood recovery in streams with riparian forest restoration. New Zealand Journal of Marine and Freshwater Research (43): 673-688.
Diaz R.J., Rosenberg R. 2008. Spreading dead zones and consequences for marine ecosystems. Science (321): 926-929.
Elliot A., Alexander R., Schwarz G., Shankar U., Sukias J., McBride G. 2005. Estimation of nutrient sources and transport for New Zealand using the hybrid mechanistic-statistical model SPARROW. Journal of Hydrology: New Zealand (44): 1-27.
Elliott M., Burdon D., Hemingway K.L., Apitz S.E. 2007. Estuarine, coastal and marine ecosystem restoration: Confusing management and science - A revision of concepts. Estuarine Coastal and Shelf Science (74): 349-366.
Environmental Communications Limited 2010. Integrated cathement management - a review of literature and practice. A report for the Ministry for the Environment. . 158p.
Forrest B., Gillespie P., Cornelisen C., Rogers K. 2007. Multiple indicators reveal river plume influence on sediments and benthos in a New Zealand coastal embayment. New Zealand Journal of Marine and Freshwater Research (41): 13-24.
Frew R., Hunter K., Beyer R. 1996. Cadmium in Oysters and Sediments From Foveaux Strait, New Zealand. Proceedings of the Trace Element Group of New Zealand, 1996 Waikato University.,
Fukunaga A., Anderson M.J., Webster-Brown J.G., Ford R.B. 2010. Individual and combined effects of heavy metals on estuarine infaunal communities. Marine Ecology-Progress Series (402): 123-136.
GESAMP 2001. Protecting the oceans from land-based activities. Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment. Nairobi, United Nations Environment Program. 168.
Glade T. 2003. Landslide occurrence as a response to land use change: A review of evidence from New Zealand. Catena (51): 297-314.
Goff J.R. 1997. A chronology of natural and anthropogenic influences on coastal sedimentation, New Zealand. Marine Geology (138): 105-117.
Grange K., Tovey A., Hill A.F. 2003. The spatial extent and nature of the bryozoan communities at Separation Point, Tasman Bay. 22 p.
Griffiths G., Glasby G. 1985. Input of River-derived sediments to the New Zealand Continental Shelf: I. Mass. Estuarine, Coastal and Shelf Science (21): 773-784.
Halpern B., Selkoe K., Micheli F., Kappel C. 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation Biology (21): 1301-1315.
Haro A., Richkus W., Whalen K., Hoar A., Busch W.D., Lary S., Brush T., Dixon D. 2000. Population decline of the American eel: Implications for research and management. Fisheries (25): 7-16.
Hayward B.W., Grenfell H.R., Sabaa A.T., Morley M.S., Horrocks M. 2006. Effect and timing of increased freshwater runoff into sheltered harbor environments around Auckland City, New Zealand. Estuaries and Coasts (29): 165-182.
Hewawasam T., von Blanckenburg F., Schaller M., Kubik P. 2003. Increase of human over natural erosion rates in tropical highlands constrained by cosmogenic nuclides. Geology (31): 597-600.
Hicks, D., Shankar, U., McKerchar, A.I., Basher, L., Jessen, Lynn, I., Page, M., 2011. Suspended sediment yields from New Zealand rivers. Journal of Hydrology (NZ) 50, 81-142.
Hicks, D., Shankar, U., 2003. Sediment from New Zealand rivers, NIWA Chart, Miscellaneous Series No.79.
Hill, D.; Dubey, J.P. 2002: Toxoplasma gondii: transmission, diagnosis and prevention. Clinical Microbiology and Infection 8(10): 634–640.
Hooker S., Redfearn P. 1998. Preliminary survey of toheroa (*Paphies ventricosa*) populations on Ninety Mile Beach and possible impacts of vehicle traffic. NIWA Client Report: AK98042. 34p.
IPCC 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri R.andReisinger A.E., eds. Geneva, Switzerland., pp 104.
Kennish M.J. 2002. Environmental threats and environmental future of estuaries. Environmental Conservation (29): 78-107.
Kneitel J.M., Perrault D. 2006. Disturbance-induced changes in community composition increase species invasion success. Community Ecology (7): 245-252.
Lipcius R.N., Eggleston D.B., Schreiber S.J., Seitz R.D., Shen J., Sisson M., Stockhausen W.T., Wang H.V. 2008. Importance of metapopulation connectivity to restocking and restoration of marine species. Reviews in Fisheries Science (16): 101-110.
Lundquist C.J., Oldman J.W., Lewis M.J. 2009. Predicting suitability of cockle Austrovenus stutchburyi restoration sites using hydrodynamic models of larval dispersal. New Zealand Journal of Marine and Freshwater Research (43): 735-748.
Marsden I., Adkins S. 2009. Current status of cockle bed restoration in New Zealand Aquaculture international ISSN: 0967-6120 (Print) 1573-0143X (Online).
Milliman J., Syvitski J. 1992. Geomorphic/Tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers. The Journal of Geology (100): 525-544.
Moller J., Moller S., Futter J., Moller J., Harvey J., White H., Stirling F., Moller H. 2009. Potential impacts of vehicle traffic on recruitment of Toheroa (*Paphies ventricosa*) on Oreti Beach, Southland, New Zealand. Dunedin, University of Otago. 61p.
Morrisey D.J. 2000. Predicting impacts and recovery of marine farm sites in Stewart Island New Zealand, from the Findlay-Watling model. Aquaculture (185): 257-271.
Morrison M., Lowe M., Parsons D., Usmar N., McLeod I. 2009. A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. 100p.
Morrison M., Parkinson D. 2008. Distribution and abundance of toheroa (Paphies ventricosa) on Ninety Mile Beach, March 2006. New Zealand Fisheries Assessment Report 2008/26, ed. 27p.

Nellemann C., Hain S., Alder J.E. 2008. In Dead Water - Merging of climate change with pollution, over-harvest, and infestations in the world's fishing grounds. United Nations Environment Programme, GRID-Arendal,. 64p.

Parkyn S., Davies-Colley R., Halliday N., KJ C., GF C. 2003. Planted Riparian Buffer Zones in New Zealand: Do They Live Up to Expectations? Restoration Ecology (11): 436-447.

Piola R.F., Johnston E.L. 2008. Pollution reduces native diversity and increases invader dominance in marine hard-substrate communities. Diversity and Distributions (14): 329-342.

Roni P., Hanson K., Beechie T. 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management (28): 856-890.

Seaman W. 2007. Artificial habitats and the restoration of degraded marine ecosystems and fisheries. Hydrobiologia (580): 143-155.

SPREP 2010. South Pacific Regional Environment Programm, Strategic Plan 2011-2015: Draft for comment. available at www.sprep.org, ed. 29p.

Stephenson G. 1999. Vehicle impacts on the biota of sandy beaches and coastal dunes: A review from a New Zealand perspective. Science for Conservation (121): 48p.

Stewart M.J., Creese R.G. 1998. Restoration of the New Zealand little necked clam, *Austrovenus stutchburyi*. Journal of Shellfish Research (17): [np].

Taylor F.J., Taylor N.J., Walsby J.R. 1985. A bloom of planktonic diatom *Ceratulina pelagica* off the coastal northeastern New Zealand in 1983, and its contribution to an associated mortality of fish and benthic fauna. Internationale Revue der gesamten Hydrobiologie und Hydrographie. 70: 773-795.

Thrush S., Hewitt J., Cummings V., Ellis J., Hatton C., Lohrer A., Norkko A. 2004. Muddy waters: elevating sediment input to coastal and estuarine habitats. Frontiers in ecology and the environment (2): 299-306.

Thrush S.F., Hewitt J.E., Hickey C.W., Kelly S. 2008. Multiple stressor effects identified from species abundance distributions: Interactions between urban contaminants and species habitat relationships. Journal of Experimental Marine Biology and Ecology (366): 160-168.

Whetton P., Mullan A.B., Pittock A. 1996. Climate change scenarios for Australia and New Zealand. In: Bouma W., Pearman G.andManning M. (Eds.) Greenhouse: coping with climate change. CSIRO Publishing, Collingwood, Australia. 145-168.

Wilkinson, R., McKergow, L., Davies-Colley, R., Ballantine, D., Young, R., 2011. Modelling storm-event E. coli pulses from the Motueka and Sherry Rivers in the South Island, New Zealand. New Zealand Journal ofMarine and Freshwater Research 45, 369-393.

THEME 5: MARINE BIODIVERSITY

11. Biodiversity

Scope of chapter	Provide an overview of the MPI Biodiversity Programme and address: National and global context of NZ marine biodiversity research; Research findings and progress of the MPI Biodiversity Research Programme from 2000–2012; including one-off whole-of-government research initiatives administered under this programme (e.g. Ocean Survey 20/20 Biodiversity and Fisheries projects; International Polar Year Census of Antarctic Marine life project 2007)
Geographic area	New Zealand Territorial Seas, EEZ and Continental shelf extension (BioInfo); South-west Pacific Region associated with South Pacific Regional Fisheries Management Organisation (SPRFMO);Antarctic Ross Sea region (BioRoss)
Focal issues	New Zealand waters have globally significant levels of marine biodiversity, and productivity particularly coastal habitats, offshore island habitats and underwater topographical features such as seamounts, and canyons. With the exception of shallow sea ice impacted coastal habitats, these features apply also to the Ross Sea region. Adjacent international waters in the SPRFMO area contain areas likely to constitute Vulnerable Marine Ecosystems (VMEs),
Key progress *2011-12*	• Predictive habitat modelling has identified potential areas of VMEs in SPRFMO areas • Significant progress has been made on mapping deepsea fisheries habitat at risk from ocean acidification; research on shellfish has identified thermal stress and ocean acidification as two areas of concern for New Zealand in an increasing CO_2 world. • Progress has been made towards developing a national Marine Environmental Monitoring Programme • A major project on changes in marine shelf systems over the past 1000 years has almost reached completion. • IPY and Chatham Challenger completed with many outputs and leveraging opportunities
Emerging issues	• The combined effects of multiple stressors arising from climate change and a range of otheranthropogenic activities on biodiversity and marine ecosystems (structure and function) are likely to be large and complex. • Keen interest in the development of ecosystem approaches to marine resource management is developing. • The nature and functional role of marine microbial biodiversity in large scale biogeochemical and ecosystem processes are important but not well understood. • Genetic and life-history stage connectivity between and within large scale habitats may be important to the size and placement of protection zones. • Apart from fisheries data, long-term (eg decadal to millenia) observations of variability and change in the marine environment (including biodiversity) are not yet generally available at geographic scales appropriate for national reporting . • Metrics for assessing the effectiveness of current protection measures in safeguarding marine biodiversity and aquatic ecosystem health in NZ and Ross Sea region are inadequate. • Economic value of ecosystem goods and services provided by marine biodiversity to current and future generations are not addressed in extractive business models. • Marine biodiversity and its monitoring, loss reduction and enhancement

	are emerging requirements for signatories (including New Zealand) to the CBD Aichi-Nagoya Agreement 2010 • Geo-engineering methods including ocean fertilisation continues to be advocated in some areas of international climate change mitigation • Meeting New Zealand responsibilities participate in international data collection programmes, e.g., IMOS, SOCPR ARGO, BIO-ARGO,
MPI Research (current)	55 biodiversity projects commissioned over the period 2000-12; Currently in 4th year of a 5 year programme to address seven science objectives in the Biodiversity Programme: 1 characterisation and description; 2 ecosystem scale biodiversity; 3 functional role of biodiversity; 4 genetics; 5 ocean climate effects; 6 indicators; 7 threats to biodiversity. MPI biodiversity research has strong synergies with marine research funded by MPI Aquatic and Environment Working Group (AEWG), Ministry of Business Innovation and Employment (MBIE), Department of Conservation (DOC), Land Information New Zealand (LINZ), other sections within the Ministry for Primary Industries (MPI), Ministry for the Environment (MfE),Statistics New Zealand (Stats NZ), Te Papa and Crown Research Institutes
NZ Research and associated initiatives (current)	Research programmes and database initiatives on Marine Biodiversity are run at University of Auckland (World Register of Marine Species (WoRMS), marine reserves, rocky reef ecology, Ross Sea meroplankton, genetics); Auckland University of Technology, University of Waikato (soft sediment functional ecology and biodiversity), Victoria University of Wellington (monitoring marine reserves, population genetics), University of Canterbury (intertidal and subtidal ecology, kelp forests and biodiversity), University of Otago (land-use effects, bryozoans, inshore ecology, ocean acidification), National Institute of water and Atmospheric Research (NIWA) and Cawthron Institute. Former MBIE programmes i.e., Coasts & Oceans OBI C01X0501, Marine Biodiversity & Biosecurity OBI C01X0502, are now part of Core Funding managed by NIWA through the Coast and Oceans Centre; Protecting Ross Sea Ecosystems C01X1001, Climate Change Effects in the Ross Sea C01X1226, Coastal Conservation Management C01X0907, Impacts of resource use on vulnerable deep-sea communities C01X0906; DOC, MPI, NIWA and Landcare Research - NZ Organisms Register.
Links to Fisheries 2030 and MPI's Our Strategy 2030	Fisheries 2030 Environmental Outcome Objective 1; environmental principles of Fisheries 2030 include: Ecosystem-based approach, Conserve biodiversity: Environmental bottom lines, Precautionary approach, Responsible international citizen, Inter-generational equity, Best available information, Respect rights and interests (MPI 2009). MPI's Strategy "Our Strategy 2030": two key stated focuses are to maximise export opportunities and improve sector productivity; increase sustainable resource use, and protect from biological risk
Related chapters/issues	Multiple use, land-based effects, variability and change, marine monitoring, cumulative effects of use and extraction in the marine environment, protected areas; benthic impacts, ecosystem approaches to fisheries and marine resource management.

11.1. *Introduction*

This chapter summarises the development and progress of the MPI Marine Biodiversity Research Programme 2000-2012 and reviews the work commissioned in the context of national and global concerns about biodiversity and the maintenance of the marine ecosystem in a healthy functioning state, as identified by the New Zealand Biodiversity Strategy (NZBS, Anon 2000).

11.1.1. Halting the decline in biodiversity

In June 2000, the '*New Zealand Biodiversity Strategy– Our Chance to Turn the Tide'* (*NZBS*) with the over-arching objectives "to halt the decline of biodiversity in New Zealand and protect and enhance the environment" was launched as part of New Zealand's commitment to the international Convention on Biological Diversity 1993 (Anon 2000). To meet long-term goals of the NZBS, a comprehensive plan, with stated objectives and actions F[1]F, was developed to address biodiversity issues in terrestrial, freshwater and marine systems. The Desired Outcomes by 2020 for the marine environment (Coasts and Oceans, Theme 3) in the NZBS were stated as:

- "New Zealand's natural marine habitats and ecosystems are maintained in a healthy functioning state and degraded marine habitats are recovering.
- A full range of marine habitats and ecosystems representative of New Zealand's indigenous marine biodiversity is protected.
- No human-induced extinctions of marine species within New Zealand's marine environment have occurred.
- Rare or threatened marine species are adequately protected from harvesting and other human threats, enabling them to recover.
- Marine biodiversity is appreciated, and any harvesting or marine development is done in an informed, controlled and ecologically sustainable manner."

In the marine environment, biodiversity decline is characterised not only by extinctions or reduction in species richness and abundance, but also by environmental degradation such as species invasion and hybridisations, habitats that have been diminished or removed, and the disruption of ecosystem structure and function, as well as ecological processes (e.g. biological cycling of water, nutrients and energy). Measuring the decline of marine biodiversity is complicated by the 'shifting baseline syndrome', a common obstacle to useful biodiversity assessment and monitoring[1]. Furthermore the size range of organisms sampled is often limited to macroscopic. Changes (declines) in biodiversity metrics at a macroscopic level may not detect potentially large changes in biodiversity in smaller sized organisms below our sampling threshold that may also be critical to marine ecosystem health and well-being.

Responsibility for addressing Theme 3 of the Biodiversity Strategy was allocated across government departments with active roles in the management of the marine environment, including the Department of Conservation (DOC), the Ministry for Environment (MfE), and the Ministry of Fisheries (now MPI)[2].

11.1.2. Defining biodiversity

New Zealand's Biodiversity Strategy defines biodiversity as:

[1] A National Approach to Addressing Marine Biodiversity Decline (Australian Government-available on line at www.environment.gov.au/coasts/publications/marine-diversity-decline/index.html
[2] https://www.biodiversity.govt.nz/picture/doing/programmes/index.html

"The variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part [as defined by the CBD]; this includes diversity within species, between species and of ecosystems [as further disaggregated for New Zealand purposes]. Components include:

- *Genetic diversity: the variability in the genetic make-up among individuals within a single species. In more technical terms, it is the genetic differences among populations of a single species and those among individuals within a population.*
- *Species diversity – the variety of species—whether wild or domesticated— within a particular geographic area.*
- *Ecological diversity – the variety of ecosystem types (such as forests, deserts, grasslands, streams, lakes wetlands and oceans) and their biological communities that interact with one another and their non-living environments."*

MPI's Biodiversity programme is concerned primarily with research to underpin NZBS Theme 3: Biodiversity in Coastal and Marine Ecosystems:

> *"Coastal and marine ecosystems include estuaries, inshore coastal areas and offshore areas, and all the resident and migratory marine species that live in them.*

New Zealand's ocean territory (including territorial sea and the recent continental shelf extension[3]) is very large relative to the area of land[4] and includes some 15-18,000 kilometres of coastline extending from the sub-tropical north to the cool Subantarctic waters to the south. New Zealand also has a rich marine biodiversity that has been recognised as being globally significant with up to 44% estimated as endemic and comprising up to 10% of global marine biodiversity Gordon *et al.* 2010.

An estimated 34,400 marine species and associated ecosystems around New Zealand deliver a wide range of environmental goods and services that sustain considerable fishing, aquaculture and tourism industries as well as drive major biogeochemical and ecological processes. Several factors would suggest that this estimate of marine species number is conservative. Such factors include the region's size, the depth range, geomorphological and hydrological complexity as well as limited water column sampling and limited benthic sampling, especially below 1500 metres. If recent indications of massive oceanic microbial diversity are taken into account (e.g. Sogin *et al.* 2006) then the number above is certainly conservative.

New Zealand's marine biodiversity is affected by many uses of the marine environment, particularly fishing, aquaculture, shipping, petroleum and mineral extraction, renewable energy, tourism and recreation[5]. Impacts from changing land use, including agricultural, urban run-off and coastal development can also affect marine biodiversity (Morrison *et al.* 2009). The potential loss of marine biodiversity and possible functionality caused by climate change and ocean acidification are of increasing concern worldwide (e.g., Guinotte *et al.*, 2006; Ramirez-Llodra *et al.* 2011; as well as in New Zealand–see NZ Royal Society Workshop papers[6]). The growing arrival of non-indigenous (sometimes invasive) marine species is also a threat to local biodiversity (e.g., Coutts and Dodgshun 2003, Cranfield *et al.* 2003, Gould *et al.* 2008 Russel *et al.* 2008, Williams *et al.* 2008).

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[3] http://www.mfat.govt.nz/Treaties-and-International-Law/04-Law-of-the-Sea-and-Fisheries/NZ-Continental-Shelf-and-Maritime-Boundaries.php

[4] NZ sea area is ~5.8 million km^2 including TS, EEZ and continental shelf extension; 4th largest in the world; www.linz.govt.nz

[5] http://www.royalsociety.org.nz/media/Future-Marine-Resource-Use-web.pdf
http://www.stats.govt.nz/browse_for_stats/environment/natural_resources/fish.aspx

[6] : http://www.royalsociety.org.nz/publications/policy/yr2009/ocean-acidification-workshop/

Understanding about New Zealand's coastal marine environment and its land-sea interactions has progressed although knowledge about the state of the marine environment and marine biodiversity on a national scale remains limited. Current knowledge about New Zealand's and the Ross Sea's marine biodiversity suggests that it may generally be in better shape than that of many other countries (Costello *et al.* 2010, Gordon *et al.* 2010). However, New Zealand is less well placed when it comes to understanding the threats to marine biodiversity (Costello *et al.* 2010, MacDiarmid *et al.* 2012) and the nature of their impacts. There are significant concerns with the decline of some key species (MfE 2007), localised impacts on habitats and conditions (Thrush and Dayton 2002, Cryer *et al.* 2002, Clark *et al.* 2010a., Gordon *et al.* 2010, Clark & Dunn 2012) and emerging threats to the marine environment (MacDiarmid *et al.* 2012) despite the combined efforts of New Zealand's government and stakeholders. Global scale threats associated with the potential effects of ocean acidification on microbial diversity and their roles in biogeochemical processes have yet to be quantified but could have EEZ wide implications (Bostock *et al.* 2012).

New Zealanders increasingly value environmental, economic and social aspects of marine biodiversity and the ecosystem services that a healthy marine environment provides. They also value the need to sustainably manage the use of coastal and marine environments and maintain biological diversity as reflected by recent policy statements by the New Zealand Government.[7 8] A broad range of legislation, regulations and policies are in place to manage and regulate uses of the marine environment, to protect marine biodiversity, to improve management of the coastal and marine environment and to meet world-wide consumer demands for improved sustainability. The most recent introduction is the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 which will come into effect once the first set of regulations is promulgated. However, progress on an integrated oceans policy and strategic direction for implementation of New Zealand's Biodiversity Strategy has been slow compared with other countries such as Canada, the UK, the USA and Australia (Peart *et al.* 2011).

11.1.3. Implementation of New Zealand's Biodiversity Strategy

A number of initiatives have been supported by MPI to meet the goals of the NZBS. Commitments include the creation of NABIS (the National Aquatic Biodiversity Information System)[9], the administration of the MPI Biodiversity Research Programme, convening and chairing the Biodiversity Research Advisory Group[10], and developing a Marine Protected Area policy with DOC. DOC also surveys and monitors aspects of marine biodiversity, particularly in marine reserves[11]. MfE has encouraged Regional Councils to develop coastal monitoring programmes and with MPI and DOC, initiated an approach to Marine Environmental Classification[12]. Biodiversity related research has also been carried out through MPI's Biosecurity Science Strategy. One result includes mapping and valuation of marine biodiversity around New Zealand's coastline[13].

Marine biodiversity research is also supported through public good funding and is conducted mainly by Universities and CRIs. Both have contributed to New Zealand's high profile on the international scientific network for marine biodiversity through participation in global initiatives such as the Census of Marine Life as well as to local programmes that have improved understanding of the role of

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[7] MfE Proposed National Policy Statement on Indigenous Biological Diversity (biodiversity) under the Resource Management Act 1991 www.mfe.govt.nz/publications/biodiversity/indigenous-biodiversity/proposed-national-policy-statement/statement.pdf

[8] New Zealand Coastal Policy Statement 2010 www.doc.govt.nz/conservation/marine-and-coastal/coastal-management/nz-coastal-policy-statement/

[9] NABIS is an interactive database accessible at www.nabis.govt.nz

[10] www.fish.govt.nz/en-nz/Research+Services/Background+Information/Biodiversity+background.htm

[11] www.doc.govt.nz

[12] www.mfe.govt.nz/issues/biodiversity/initiatives/marine.html#regional

[13] www.biosecurity.govt.nz/biosec/research

biodiversity in the marine ecosystem. The Museums of Auckland, Canterbury, Otago and Wellington (Te Papa) also conduct biodiversity sampling expeditions and national collections of specimens have been set up within Museums and also at NIWA. Regional Councils give effect to NZBS; Coastal Biodiversity Policy Statement 2011, protected areas and spatial planning.

11.1.4. New challenges and agendas

Since the launch of the Biodiversity Stratey, there have been substantial changes in Government goals for New Zealand. In July 2009, the Minister of Science set an overarching goal for research science and technology[14]:

> "to improve New Zealand's economic performance while continuing to strengthen our society and protect our environment".

This goal is reflected in first progress report on "Building Natural Resources" as part of the Business Growth Agenda[15] released December 2012. The Business Growth Agenda sets an ambitious goal of increasing the ratio of exports to GDP to 40% by 2025. Meeting the target will require the value of our exports to double in real terms by 2025. The report states that one of the goals is to "Make the most of the considerable opportunities for New Zealand to gain much greater value from its extensive marine and aquaculture resources".

The biological economy of the sea (currently largely fisheries and aquaculture, oil and gas, minerals) is a significant part of the overall economy and may have potential for growth (e.g. unlocking the potential of the fisheries sector–Fisheries 2030 (MPI 2009[16]). It is essential that the aquatic environment and biodiversity on which industry depends are not adversely affected by these or other impacting activities.

Bodies such as the Marine Stewardship Council (MSC[17]) require fisheries to satisfy stringent environmental requirements to achieve certification. Many fisheries management systems throughout the globe have begun to develop policies that are ecosystem based. Implementation has met with varied success, and measurement of success is a challenge.

The large scale threats to the marine environment posed by increasing global impacts of anthropogenic stressors such as climate change and ocean acidification, increasing exploitation of resources (living or non-living) and the cumulative effect of multiple uses of the marine environment (e.g., renewable energy, commercial fisheries, recreational fisheries, aquaculture, hydrocarbon and mineral extraction) remain.

Scientific research has provided information about the predicted distribution and abundance of marine biodiversity in some areas of New Zealand's coasts and oceans, but progress on validation in areas that remain unsampled has been slow. The structure and function of biodiversity of macrofauna within some New Zealand and Ross Sea marine ecosystems is well understood and available information has been used to assess the habitat types at greatest risk from disturbance, particularly fishing. However, the proportions of marine habitat types should be or can be protected to maintain a healthy aquatic environment is unknown.

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[14] MoRST feedback document on New Zealand's research science and technology: www.morst.govt.nz/Documents/publications/policy

[15] https://www.mbie.govt.nz/what-we-do/business-growth-agenda/pdf-folder/BGA-Natural-Resources-report-December-2012.pdf

[16] MFish (2009). Fisheries 2030 report. New Zealanders maximising benefits from the use of fisheries within environmental limits available from http://www.fish.govt.nz/en-nz/Fisheries+2030/default.htm

[17] Marine Stewardship Council www.msc.org

There is growing awareness of the likely importance of the huge diversity, biomass and species mix of micro-organisms, nano- and pico-plankton, and is a fast developing field of research. The rate of change and the resilience of biodiversity to the cumulative effect of multiple stressors across large spatial scales (e.g. ocean acidification, temperature increase and oxygen depletion), particularly as utilisation of marine resources increases, remain semi-quantified (Ramerez-Llodra *et al.* 2011). Understanding the dynamics of climate change and predicting the impacts on food webs and fisheries are only just being investigated (e.g., Fulton 2004, Brown *et al.* 2010, Garcia and Rosenberg 2010).

11.2. *Global understanding and developments*

In April 2002, the Parties to the Convention on Biological Diversity (CBD) committed to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth. This target was subsequently endorsed by the World Summit on Sustainable Development and the United Nations General Assembly and was incorporated as a target under the Millennium Development Goals[18].

The third edition of the Global Biodiversity Outlook confirmed that the 2010 biodiversity target had not been met, and the CBD 2010 Strategic Plan notes that "actions [to achieve the 2010 target] have not been on a scale sufficient to address the pressures on biodiversity[19]. Moreover there has been insufficient integration of biodiversity issues into broader policies, strategies, programmes and actions, and therefore the underlying drivers of biodiversity loss have not been significantly reduced". The Strategic Plan includes a new series of targets for 2020 under the heading "*Taking action now to decrease the direct pressures on biodiversity*". The Strategic Plan for 2011–2020 was updated, revised and adopted by over 200 countries, including New Zealand[20].

The eleventh meeting of the Conference of the Parties to the Convention on Biological Diversity (held 8-19 Oct 2012)[21] generated some agreed outcomes of relevance for New Zealand, in particular:

- There was confirmation that the application of the scientific criteria for EBSAs and the selection of conservation and management measures is a matter for states and relevant inter-governmental bodies but that it is an open and evolving process that should continue to allow ongoing improvement and updating as new information comes to hand
- It was recognised that there was a need to promote additional research and monitoring in accordance with national and international laws, to improve the ecological or biological information in each region with a view to facilitating the further description of the areas described
- There is a tentative schedule of further regional workshops to facilitate the description of areas meeting the criteria for EBSAs.

New Zealand government agencies will need to consider how to update the NZBS to better align with the Aichi Biodiversity targets.

[18] UNEP's work to promote environmental sustainability, the object of Millenium Development Goal 7, underpins global efforts to achieve all of the Goals agreed by world leaders at the Millennium Summit http://www.unep.org/MDGs/
[19] www.cbd.int/2010-target
[20] draft updated and revised Strategic Plan for the Convention on Biological Diversity for the post-2010 period (UNEP/CBD/WG-RI/3/3) http://www.cbd.int/nagoya/outcomes/
[21] http://www.cbd.int/doc/?meeting=cop-11 UNEP/CBD/COP/11/23 Marine and Coastal Biodiversity: Revised Voluntary Guidelines for the Consideration of Biodiversity in Environmental Impact Assessments and Strategic Environmental Assessments in Marine and Coastal Areas

11.2.1. The decade of biodiversity 2011-2020

The United Nations General Assembly at its 65th session declared the period 2011-2020 to be "the United Nations Decade on Biodiversity, with a view to contributing to the implementation of the Strategic Plan for Biodiversity for the period 2011-2020" (Resolution 65/161). It will serve to support and promote implementation of the objectives of the Strategic Plan for Biodiversity and the Aichi-Nagoya Biodiversity Targets. The principal instruments for implementation are to be National Biodiversity Strategies and Action Plans or equivalent instruments (NBSAPs). CBD signatory nations are expected to revise their NBSAPs and to "ensure that this strategy is mainstreamed into the planning and activities of all those sectors whose activities can have an impact (positive and negative) on biodiversity" (http://www.cbd.int/nbsap/). Throughout the United Nations Decade on Biodiversity, governments are encouraged to develop, implement and communicate the results of progress on their NBSAPs as they implement the CBD Strategic Plan for Biodiversity.

There are five strategic goals and 20 ambitious yet achievable targets. Collectively known as the Aichi Targets, they are part the Strategic Plan for Biodiversity. The five Strategic Goals are:

- Goal A - Address the underlying causes of biodiversity loss by mainstreaming biodiversity (NBSAPs) across government and society
- Goal B - Reduce the direct pressures on biodiversity and promote sustainable use
- Goal C - Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
- Goal D - Enhance the benefits to all from biodiversity and ecosystem services
- Goal E - Enhance implementation through participatory planning, knowledge management and capacity building

Targets 6-11 specifically refer to fisheries and marine ecosystems and are provided in Appendix 1 to this Chapter.

The CBD also calls for renewed efforts specifically on coastal and marine biodiversity: "The road ahead for coastal areas lies in better and more effective implementation of integrated marine and coastal area management in the context of the Convention's ecosystem approach. This includes putting in place marine and coastal protected areas to promote the recovery of biodiversity and fisheries resources and controlling land-based sources of pollution. For open ocean and deep sea areas, sustainability can only be achieved through increased international cooperation to protect vulnerable habitats and species."[22] The CBD held regional workshops during 2011 to identify information sources that might inform the location of Ecologically or Biolologically Sensitive Areas (EBSAs). New Zealand participated in the SW Pacific workshop, and EBSAs were identified[23] The criteria for identifying EBSAs and Vulnerable Marine Ecosystems as recommended through UNGA and managed by Regional Fisheries Management Organisations[24]. The 2012 SPRFMO Science Working Group noted that the differing approaches to identifying VMEs and EBSAs could lead to conflicts in how areas possible in need of protection are defined.

11.2.2. Global marine assessment

The biological diversity of the 72% of the planet covered by seawater is a crucial component of global resource security, ecosystem function and to climate dynamics. The Marine Biodiversity Outlook

[22] www.cbd.int/marine/done.shtml
[23] www.cbd.int/doc/meetings/cop/cop-11/official/cop-11-03-en.doc
[24] http://www.un.org/Depts/los/consultative_process/documents/no4_spc2.pdf

Reports and Summaries prepared by UNEP's Regional Seas Programme for the 10th Conference of Parties of the Convention on Biological Diversity (CBD) held in 2010 provide the first systematic overview at a sub-global scale of the state of knowledge of marine biodiversity, the pressures it faces currently and the management frameworks in place for addressing those pressures[25].

The regional reports reflect a poor outlook for the continuing well being of marine biodiversity, which faces increasing pressures in all regions from land sourced pollution, ship sourced pollution and impacts of fishing. These pressures are serious and generally increasing despite measures in place to address them. They are amplified by predicted impacts of ocean warming, acidification and habitat change arising from climate and atmospheric change. Without significant management intervention marine biological diversity is likely to deteriorate substantially in the next 20 years with growing consequences for resource and physical security of coastal nations.

With respect to fisheries, the main findings of the reports are that in most regions fisheries peaked at some point between the mid-1980s and mid-2000s that catch expansion is not possible in many cases and that increased exploitation levels would lead to lower catch levels.

All regions report increases in shipping at levels which generally reflect annual economic growth. All regions report progress in the establishment of Marine Protected Areas but current levels of 1.2% of global ocean surface or 4.3% of continental shelf areas fall far short of the 10% target set by CBD COP7 in 2004. It is likely to be many years before this target is reached. The figures do not include some managed fishery areas that have objectives consistent with multiple sustainable use and overall objectives for conservation but even if these are taken into account the proportion managed with objectives that explicitly address sustainability of biodiversity or ecosystem processes is inadequate. The need to plan and implement ecosystem scale and ecosystem-based management of the seas is urgent.

After many years of international negotiations on the need to strengthen the science-policy interface on biodiversity and ecosystem services at all levels, more than 90 governments (including New Zealand) agreed in April 2012 to officially establish the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[26]. It will be a leading global body providing scientifically sound and relevant information to support more informed decisions on how biodiversity and ecosystem services are conserved and used around the world.

The United Nations Conference on Sustainable Development (UNCSD), also known as the Rio+20 Conference (June 2011)[27] had a strong sustainability focus and generated an outcome document entitled "the future we want" which had a section on oceans (para 158 - 177) including:

- Support for the Regular Process of Global Reporting and Assessment of the State of the Marine Environment established under the General Assembly and looked forward to the completion of the first global integrated assessment of the state of the marine environment by 2014[28].
- The ongoing work of the Ad Hoc Open-ended Informal Working Group on Study Issues Relating to the Conservation and Sustainable Use of Marine Biodiversity Beyond Areas of National Jurisdiction and the wish to, by the end of the 69th session (2014) make a decision about the development of an international instrument under UNCLOS.

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[25] UNEP (2003) Global Marine Assessments: a survey of global and regional marine environmental assessments and related scientific activities. UNEP-WCMC/UNEP/UNESCO-IOC. 132p available online at www.unep-wcmc.org/resources/publications/ss1/GMA_Review.pdf

[26] http://www.iucn.org/what/

[27] http://sustainabledevelopment.un.org/futurewewant.html Rio +20 outcome document

[28] Integrated assessment of the state of the marine environment by 2014.
http://www.un.org/depts/los/global_reporting/Santiago_Regular_Proceess_Workshop_Presentations/GRAME_Outline_of_the_First_Integrated_Assessment_Report.pdf

- A concern about the health of oceans and marine biodiversity and the work of the IMO and relevant conventions including initiatives like the London Protocol on ocean fertilisation and teh global programme of action for the protection of the marine environment from land based activities.
- The Rio+20 outcome also endorsed a process to develop sustainable development goals (to apply to all countries) which will include oceans issues. (This is still in its nascent stage and a clear work programme will be finalised by Sept 2013).

11.2.3. Ocean climate change and ocean acidification

Ocean climate change at the global scale overshadows the existing challenges of managing local impacts causing declines in marine biodiversity in the face of current levels of human use and impact. The projected increases in temperature, acidity, severe storm incidence and sea level present major challenges for biodiversity management. This is reflected in changes at the Great Barrier Reef in Australia, which is a globally iconic marine ecosystem that has been subject to adaptive scientifically-based ecosystem-based management for more than 30 years. An Outlook Report by the Great Barrier Reef Marine Park Authority (2009) concluded that "without significant additional management intervention, some components of the ecosystem will deteriorate in the next 20 years and only a few areas are likely to be healthy and resilient in 50 years." Without strong ecosystem based management the global threats to marine biodiversity may be similar and their implications for food and physical security could be substantial.

The Outlook Report provides a reasonable understanding of the nature and extent of the problems facing marine biodiversity and marine resources. There are examples of effective actions to address some of these problems but management performance is generally insufficient and inadequately coordinated to address the growing problems of marine biodiversity decline and ecosystem change.

Climate change can adversely impact on the spatial patterns of marine biodiversity and ecosystem function through changes in species distributions, species mix and habitat availability, particularly at critical stages of species life histories. A study of the global patterns of climate change impacts on ocean biodiversity projected the distributional ranges of a sample of 1066 exploited marine fish and invertebrates for 2050 using a newly developed dynamic bioclimate envelope model which showed that climate change may lead to numerous local extinctions in the sub-polar regions, the tropics and semi-enclosed seas (Cheung *et al.* 2009). Simultaneously, species invasion is projected to be most intense in the Arctic and the Southern Ocean. With these elements taken together, the model predicted dramatic species turnovers of over 60% of the present biodiversity, implying ecological disturbances that potentially disrupt ecosystem services (Cheung *et al.* 2009).

The World Bank, together with IUCN and Environmental Services Association released a brief for decision-makers entitled, "Capturing and Conserving Natural Coastal Carbon – Building Mitigation, Advancing Adaptation [29]". This brief highlights the crucial importance of carbon sequestered in coastal wetlands and in submerged vegetated habitats such as seagrass beds, for climate change mitigation.

The Intergovernmental Panel on Climate Change (IPCC) is preparing material for the 5th IPCC Report in 2014 and for the first time includes chapters to explicitly address ocean climate change issues[30]. The Working Group I and Working Group II Contributions to the Fifth Assessment Report include chapters on the ocean (WG I) and Climate Change 2014: Impacts, Adaptation, and Vulnerability including Chapters on Coastal and Oceans ecosystems, and sections on biodiversity(WGII). Working

[29] UNFCCC COP-16 event. Cancun Messe, Jaguar. 'Blue Carbon: Valuing CO_2 Mitigation by Coastal Marine Systems. Sequestration of Carbon Along Our Coasts: Are We Missing Major Sinks and Sources?'
[30] http://www.global-greenhouse-warming.com/IPCC-5th-Report.html

Group I will consider "Ocean biogeochemical changes, including ocean acidification" in their Chapter 3 (Observations - Ocean), and "Processes and understanding of changes, including ocean acidification" in their Chapter 6 on "Carbon and other biogeochemical cycles". Working Group II will consider "Water property changes, including temperature and ocean acidification" in their Chapter 6 on "Ocean Systems". In addition, "Carbon Cycle including Ocean Acidification" has been identified as a "Cross-Cutting Theme" across (predominantly) WG1 and WG2.

Hobday *et al.* (2006) reported on the relative risks and likely impacts of ocean climate change and ocean acidification to marine life in Australian waters (Figure 11.1). This approach was extremely useful for summarising risks and threats of climate change on marine systems to policy makers and the subsequent development of the Commonwealth Environment Research Facilities (CERF) Marine Biodiversity Hub in Australia [31].

The Hub analysed patterns and dynamics of marine biodiversity through four research programmes to determine the appropriate units and models for effectively predicting Australia's marine biodiversity. These programmes were designed to develop and deliver tools needed to manage Australia's marine biodiversity in a changing ocean climate. The final report from three years intense research is available at the website[32]. Australia also has The Marine Adaptation Network that comprises a framework of five connecting marine themes (integration; biodiversity and resources; communities; markets and policy) that cut across climate change risk, marine biodiversity and resources, socio-economics, policy and governance, and includes ecosystems and species from the tropics to Australian Antarctic waters[33].

In late June 2011, two science-based reports heightened concerns about the critical state of the world's oceans in response to ocean climate change. One focuses on the potential impacts of ocean acidification on fisheries and higher trophic level ecology and takes a modelling approach to scaling from physiology to ecology (Le Quesne and Pinnegar 2011) and the other assesses the critical state of the world's oceans in relation to climate change and other stressors (Rogers and Laffoley (2011).

11.2.1. Census of Marine Life 2000–2010

In 2010, the international initiative to conduct a Census of Marine Life[34] was concluded after ten years of accessing and databasing existing records, sampling and exploration around the globe. The Census is an unprecedented collaboration among researchers from more than 80 nations to assess and explain the diversity, distribution, and abundance of life in the oceans. During the last decade, the 2,700 scientists involved in the Census have mounted 540 expeditions, identified more than 6,000 potentially new species, catalogued upward of 31 million distribution records, and generated 2,600 scientific publications. NIWA scientists were part of the team that led CenSeam[35], the seamount component of the Census of Marine Life, and scientists from NIWA and the University of Auckland played significant roles in a number of other programmes.The New Zealand IPY-CAML voyage to the Ross Sea in 2008 was a major contribution to CAML.

[31] www.marinehub.org/
[32] www.marinehub.org/
[33] arnmbr.org/content/index.php/site/aboutus/
[34] www.coml.org/results-publications
[35] www.coml.org/global-census-marine-life-seamounts-censeam

Groups	Distribution/ Abundance	Phenology	Physiology/ Morphology/ Behaviour	Impacts on biological communities	Examples of impacts
Phytoplankton	High	High	Medium	High	Temperate phytoplankton province will shrink considerably
Zooplankton	High	High	Medium	High	Acidification will dissolve planktonic molluscs
Seagrasses	Medium	Low	High	Medium	Increased dissolved carbon dioxide may increase productivity
Mangroves	Medium	Low	Medium	High	Sea level rise will destroy mangrove habitat
Kelp	High	Medium	High	High	Ranges will shift southwards as SST warms
Rocky reefs	High	Medium	High	Low	Ranges will shift southwards as temperature warms
Coral reefs	High	Medium	High	High	Acidification and warming will cause calcification problems and coral bleaching
Cold water corals	High	Low	Low	High	Ocean acidification will dissolve reefs
Soft bottom dwelling fauna	Medium	Medium	Medium	Medium	Modified plankton communities or productivity will reduce benthic secondary production
Seafloor dwelling and demersal fishes	High	Medium	Medium	High	Southward movement of species along the east and west coast of Australia
Pelagic fishes	Medium	Low	Medium	Low	Pelagic tunas will move south with warming
Turtles	High	Medium	High	Low	Warming will skew turtle sex ratios
Seabirds	Medium	Medium	Low	Low	Shift in timing of peak breeding season as temperatures warm
Total number of high impact habitats or species groups	8	2	5	7	High impacts are expected for distribution, physiology and community processes

Figure 11.1: Potential biological impacts of climate change on Australian marine life. The ratings in this table are based on the expected responses to predicted changes in Sea Surface Temperature (SST), salinity, wind, pH, mixed layer depth and sea level, and from literature reviews for each species group. The implicit assumption underlying this table is that Australian marine species will respond in similar ways to their counterparts throughout the world (Hobday *et al.* 2006.) Note: phenology means life cycle.

The Census increased the total number of known marine species by about 20,000, from 230,000 in 2000 to about 250,000 in 2010. Among the millions of specimens collected in both familiar and seldom-explored waters, the Census found more than 6,000 potentially new species and completed formal descriptions of more than 1,200 of them. It also found that some species considered to be rare are more common than previously thought (Ausubel *et al.* 2010). The digital archive (the Ocean Biogeographic Information System OBIS (http://www.iobis.org/) has now grown to 31 million observations, and the Census compiled the first regional and global comparisons of marine species diversity. It helped to create the first comprehensive list of the known marine species, and also helped to compose web pages for more than 80,000 species in the Encyclopaedia of Life[36].

Applying genetic analysis on an unprecedented scale to a dataset of 35,000 species from widely differing major groupings of marine life, the Census graphed the proximity and distance of relations among distinct species, providing new insight into the genetic structure of marine diversity. With the

[36] www.eol.org/

genetic analysis often called barcoding, the Census sometimes decreased diversity but generally its analyses expanded the number of species, especially the number of different microbes, including bacteria and archaea.

The Census has overwhelmingly demonstrated that the total number of species in the ocean remain largely unknown. The Census also demonstrated that evidence of human impacts on the oceans extends to all depths and habitats and that we still have much to learn to integrate use of resources with stewardship of a healthy marine ecosystem. The Census results could logically extrapolate to at least a million kinds of eukaryotic marine life that earn the rank of species and to tens or even hundreds of millions of kinds of microbes.

A summary of the overall state of knowledge about marine biodiversity after the Census by Costello *et al.* (2010) places New Zealand 6th out of 18 national regions based on the collective knowledge assembled by the Census National and Regional Implementation Committees (NRIC) and comparing the Spearman rank correlation coefficients between known diversity (total species richness, alien species, and endemics) and available resources, such as numbers of taxonomic guides and experts. (Figure 11.2).

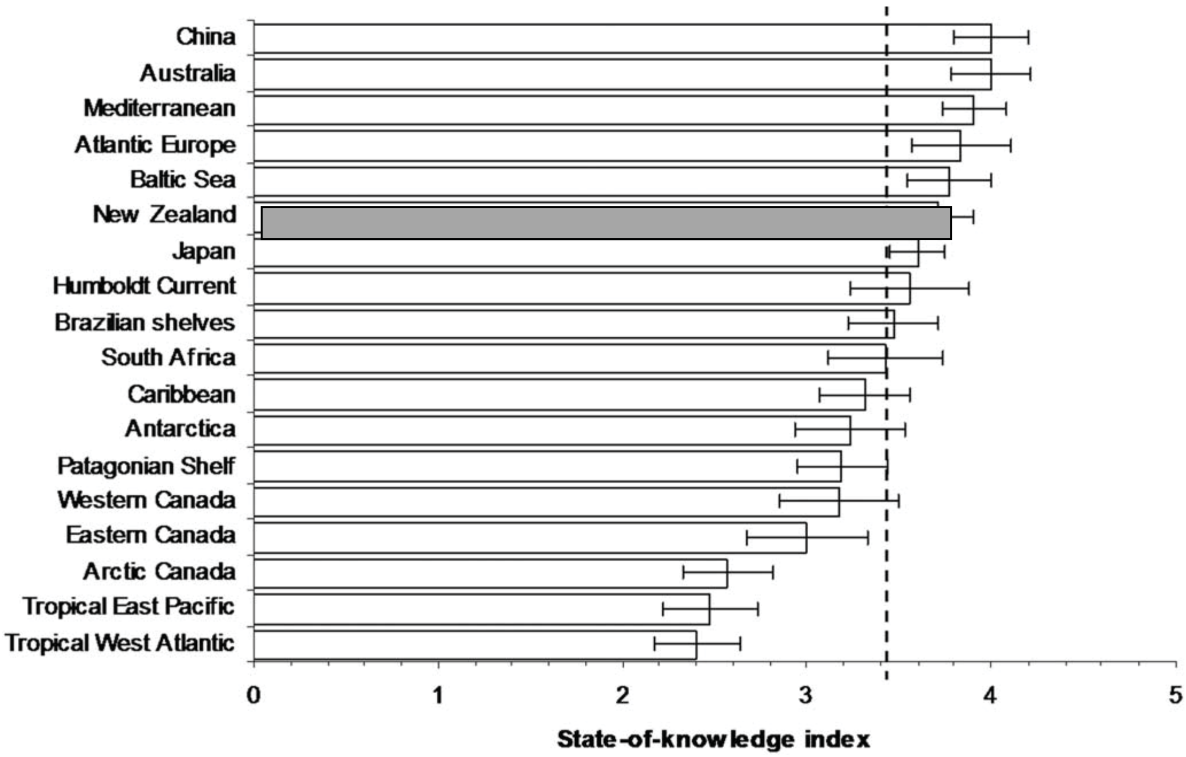

Figure 11.2: The regions are ranked by their state-of-knowledge index (mean ± standard error) across taxa. Dashed line represents the overall mean. (Image Source Costello *et al.* 2010).

All NRICs reported what they considered the main threats to marine biodiversity in their region, citing published data and expert opinions. Although the reports were not standardised, the threats identified were grouped into several overarching issues. We integrated these data on biodiversity threats so as to rank each threat from 1 (very low) to 5 (very high threat) in each region. New Zealand was placed 12th out of 1 8 regions in terms of overall threat levels to biodiversity, overfishing and alien species invasion. Habitat loss and ocean acidification were identified as the biggest threats to marine biodiversity in New Zealand (Costello *et al.* 2010).

11.2.2. Global monitoring and indicators for marine biodiversity

There are numerous schemes within and between nations to monitor the marine environment, including physical, chemical and biological components. Marine biodiversity indicators have been developed for the UK and the EU[37]. Marine environmental monitoring networks have been developed in the USA, Canada, Australia and South Africa. Global networks include the Global Ocean Observing System (GOOS) which is a permanent global system for observations, modelling and analysis of marine and ocean variables; Global Climate Observing System (GCOS[38]) which stimulates, encourages, coordinates and otherwise facilitates observations by national or international organizations. A Southern Ocean Observing System (SOOS) is under development.[39]

Others include:

- ARGO an international deepwater monitoring system of free floating buoys that are part of the integrated global observation strategy[40].
- The Ocean Observation Systems (OOS) in Canada have demonstrated many positive benefits.
- The Continuous Plankton Recorder (CPR) Surveys have been collecting data from the North Atlantic and the North Sea on the ecology and biogeography of plankton since 1931[41]. Sister CPR surveys around the globe include the SCAR SO-CPR Survey established in 1991 by the Australian Antarctic Division to map the spatial-temporal patterns of zooplankton and then to use the sensitivity of plankton to environmental change as early warning indicators of the health of the Southern Ocean. It also serves as reference for other monitoring programs such as CCAMLR's Ecosystem Monitoring Program C- EMP and the developing Southern Ocean Observing System[42].
- The Marine Environmental Change Network (MECN) is a collaboration between organisations in England, Scotland, Wales, Isle of Man and Northern Ireland collecting long-term time series information for marine waters[43].
- The MECN has developed links with other networks coordinating long-term data collection and time series. These networks include the Marine Biodiversity and Ecosystem Functioning European Union Network of Excellence (MarBEF[44]) which coordinates long-term marine biodiversity monitoring at a European level.
- New Zealand has now formed a partnership with Australia's Integrated Marine Observing System (IMOS[45]) was established in 2007. IMOS is designed to be a fully integrated national array of observing equipment to monitor the open oceans and coastal marine environment around Australasia, covering physical, chemical and biological variables. All IMOS data is freely and openly available through the IMOS Ocean Portal for the benefit of Australian and New Zealand marine and climate science as a whole. Oceans 2025[46] is an initiative of the Natural Environment Research Council (NERC) funded Marine Research Centres. This addresses environmental issues that require sustained long-term observations.

A challenge for MPI and New Zealand researchers is how to assimilate any or all of the above monitoring approaches as a means of measuring biodiversity baseline levels and the nature and extent of biodiversity changes, especially as a means of assessing the effectiveness of management measures to protect or enhance biodiversity or halt its decline.

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37 http://jncc.defra.gov.uk/page-4233
38 www.ioc-goos.org/index.php?option=com_content&view=article&id=12&Itemid=26&lang=en
39 http://www.scar.org/soos/
40 http://www.qc.dfo-mpo.gc.ca/publications/science/evaluation-assessment-eng.asp.
41 www.sahfos.ac.uk/
42 www.sahfos.ac.uk/sister-survey/sister-surveys/-southern-ocean-continuous-plankton-recorder-survey-(scar).aspx
43 http://www.mba.ac.uk/MECN/
44 http://www.marbef.org/
45 http://imos.org.au/
46 http://www.oceans2025.org/

11.2.3. Economic valuation of biodiversity

The national and global responsibility for New Zealand to maintain a strong environmental record in fisheries and other marine-based industries is increasing. There is growing awareness of international treaties and agreements that New Zealand is party to. Global markets are becoming increasingly sensitive to our national environmental record. Fishing companies who meet rigorous standards receive Marine Stewardship Council Certification for certain fisheries (currently, hoki trawl, southern blue whiting pelagic trawl and albacore tuna troll fisheries). Proposals to exploit other living marine resources or extract non-living marine resources are increasingly under scrutiny to ensure that such activities do not adversely degrade the marine environment or impact on marine living resource industries.

The invisibility of biodiversity values has often encouraged inefficient use or even destruction of the natural capital that is the foundation of our economies. A recent international initiative "The Economics of Ecosystems and Biodiversity" (TEEB)[47] demonstrates the application of economic thinking to the use of biodiversity and ecosystem services. This can help clarify why prosperity and poverty reduction depend on maintaining the flow of benefits from ecosystems; and why successful environmental protection needs to be grounded in sound economics, including explicit recognition, efficient allocation, and fair distribution of the costs and benefits of conservation and sustainable use of natural resources. Valuation is seen as a tool to help recalibrate the faulty economic compass that has led to decisions about the environment (and biodiversity) that are prejudicial to both current well-being and that of future generations.

11.3. *State of knowledge in New Zealand*

The past 750 years of human activity have impacted on marine environments. For example, depletion of fur seals and sea lions occurred from the earliest days of human settlement, not just with European arrival (Smith 2005, 2011). There was also a pulse of sedimentation coinciding with the initial clearance of 40% of NZ forests within 200 years of Polynesian settlement (McWethy *et al.* 2010). Impacts have occurred near population centres, as well as more remote areas and to depths in excess of 1000 metres (MacDiarmid *et al.* 2012, Ministry for Primary Industries 2012). In some cases by looking back over historical records it becomes apparent how much biodiversity loss has occurred. Over long time spans incremental impacts can lead to major shifts in biodiversity composition. An analysis of marine biodiversity decline over a couple of decades could miss the major changes that can occur incrementally over long periods.

While New Zealand has reasonable archaeological, historical and contemporary data on the decline in abundance of individual marine species, in some cases over a period of 750 years (e.g., MacDiarmid *et al.* in press), current trends in the status of New Zealand's marine biodiversity are difficult to determine for several reasons. These include a lack of both pre-disturbance baseline and recent information, and a lack of a nationally coordinated approach to assessing and monitoring marine biodiversity

A re-evaluation of the threat status of New Zealand's marine invertebrates was undertaken by the Department of Conservation in 2009, and identified no taxa that had improved in threat status as a result of past or ongoing conservation management action, nor any taxa that had worsened in threat status because of known changes in their distribution, abundance or rate of population decline (Freeman *et al.* 2010). The authors cautioned however that only a small fraction of New Zealand's marine invertebrate fauna had been evaluated for their threat status and that many taxa remain 'data deficient' or unlisted.

[47] TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB. www.teebweb.org/

A re-evaluation of marine mammal threat status found that relative to the previous listing, the threat status of two species worsened: the NZ sea lion (*Phocarctos hookeri*) was uplisted to Nationally Critical and the bottlenose dolphin (*Tursiops truncatus*) was uplisted to Nationally Endangered. No species was considered to have an improved status (See Chapter on marine mammales and also Baker *et al*. 2010).

The most recent State of the Environment Report in New Zealand (MfE 2007) covers terrestrial and freshwater organisms in its Biodiversity section[48]. Comment on marine biodiversity is provided in the Oceans section which states:

> "Of the almost 16,000 known marine species in New Zealand, 444 are listed as threatened. Well-known species of particular concern include both subspecies of Hector's dolphin, New Zealand sea lion, southern right whale, Fiordland crested penguin, and New Zealand fairy tern. Land-based pressures on the inshore marine environment, as well as pressures on fisheries stocks, can be expected to persist and, therefore, continue to pose a challenge to the health of the marine environment. The increasing number of introduced species brought to New Zealand through marine-based trade and travel, and climate change may exacerbate existing pressures. Further information about our marine environment is needed if we are to help set priorities for future use and protection of our oceans".

Two major knowledge gaps identified by MfE 2007 that hinder resource management are sparse biodiversity baseline information; and the lack of a systematic national-scale approach to monitoring biodiversity trends (i.e. by comparing subsequent studies to the baseline information) in New Zealand.

The most recent summary of knowledge about marine biodiversity in New Zealand is provided by Gordon (2009, 2010, 2012) and Gordon *et al.* (2010). Figure 11.3 gives a tally of 17,058 living species in the EEZ, including 4,320 known undescribed species in collections.

The Hub analysed patterns and dynamics of marine biodiversity through four research programmes to determine the appropriate units and models for effectively predicting Australia's marine biodiversity. These programmes were designed to develop and deliver tools needed to manage Australia's marine biodiversity in a changing ocean climate. The final report from three years intense research is available at the website[49.] Australia also has The Marine Adaptation Network that comprises a framework of five connecting marine themes (integration; biodiversity and resources; communities; markets and policy) that cut across climate change risk, marine biodiversity and resources, socio-economics, policy and governance, and includes ecosystems and species from the tropics to Australian Antarctic waters[50].

Species diversity for the most intensively studied animal phyla (Cnidaria, Mollusca, Brachiopoda, Bryozoa, Kinorhyncha, Echinodermata, Chordata) is more or less equivalent to that in the ERMS (European Register of Marine Species) region, an area 5.5 times larger than the New Zealand EEZ (Gordon *et al.* 2010), suggesting that the NZ region biodiversity is proportionately richer than the ERMS region (Figure 11.3).

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[48] *State of the Environment* MfE 2007.
[49] www.marinehub.org/
[50] arnmbr.org/content/index.php/site/aboutus/

Taxonomic group	No. Species[1]	State of knowledge	No. Introduced species	No. Experts	No. ID guides[2]
Domain Prokaryota[3]	**79**	**3**	**>1**	**3**	**1**
Cyanobacteria	40	2	1	1	1
Domain Eukaryota[3]	**16,979**	**3-4**	**159**	**58**	**75**
Kingdom Chromista[3]	**2,643**	**3-4**	**11**	**7**	**2**
Ochrophyta	858	4-5	11	1	1
Myzozoa incl. Dinoflagellata	249	3-4	0	2	0
Foraminifera	1141	4-5	3	2	2
Kingdom Plantae[3]	**702**	**4-5**	**12**	**12**	**3**
Chlorophyta	156	3-4	0	12	1
Rhodophyta	541	3-4	12	0	1
Tracheophyta	5	5	0	3	2
Kingdom Protozoa[3]	**43**	**2-3**	**4**	**5**	**4**
Kingdom Fungi	**89**	**3**	**0**	**1**	**0**
Kingdom Animalia[3]	**13,502**	**3-4**	**150**	**40**	**66**
Porifera	742	3	7	1	4
Cnidaria	1,116	4	23	0	6
Platyhelminthes	323	2	2	1	1
Mollusca	3,813	4	14	1	3
Annelida	792	4	32	1	2
Arthropoda (esp. Crustacea)	2,926	3-4	27	13	17
Bryozoa	953	4	24	1	4
Echinodermata	623	5	0	3	6
Tunicata	192	5	0	3	6
Other invertebrates	456	2-5	3	7	12
Vertebrata (Pisces)	1,387	4-5	6	6	7
Other vertebrates	179	5	0	4	4
TOTAL REGIONAL DIVERSITY[3]	**17,058**	**3-4**	**177**	**62**	**76**

[1]Sources of the tallies: scientific literature, books, field guides, technical reports, museum collections.
[2]Identification guides cited in Gordon *et al.* 2010.
[3]Totals from Gordon 2010, 2012 and Gordon *et al.* 2010 and unpublished NIWA data.

Figure 11.3: Diversity of marine species found in the New Zealand region (after Gordon 2010, 2012; Gordon *et al.* 2010 and current unpublished NIWA data).

In late June 2011, two science-based reports heightened concerns about the critical state of the world's oceans in response to ocean climate change. One focuses on the potential impacts of ocean acidification on fisheries and higher trophic level ecology and takes a modelling approach to scaling from physiology to ecology (Le Quesne and Pinnegar 2011) and the other assesses the critical state of the world's oceans in relation to climate change and other stressors (Rogers and Laffoley (2011).

In New Zealand, new marine research projects initiated in 2012 include 'Marine Futures' that aims to develop an agreed decision-making framework, enabling participation of all stakeholders (public, iwi, industry, government), that facilitates economic growth, improves marine stewardship and ensures that cumulative stresses placed on the environment do not degrade the ecosystem beyond its ecological adaptive capacity.(C01X1227). The 'Ross Sea Climate & Ecosystem'will model likely future changes in the physical environment of the region and potential consequences of these changes on the ecosystem in terms of functional links between the environment and the marine food web. (C01X1226). 'Management of offshore mining'will develop a clear framework that will guide appropriate and robust environmental impact assessments and the development of integrated environmental management plans for the marine-mining sector, other resource users and resource management agencies. (C01X1228)

Core purpose funding within the Coasts and Oceans Centre at NIWA include "Managing Marine Stressors: Quantifying and predicting the effects of natural variability, climate change and anthropogenic stressors to enable ecosystem-based approaches to the management of New Zealand's marine resources" and within the Fisheries Centre, "Ecosystem Approaches to Fisheries Management: Determine the impact of fisheries on the aquatic environment to inform an ecosystem-based approach to fisheries management and contribute to broader ecosystem-based management approaches in conjunction with the Coasts & Oceans Centre.

11.3.1. The MPI Biodiversity Research Programme

The recognition of increasing societal expectation to use fisheries management measures that will achieve biodiversity conservation has signalled by MPI through Fisheries 2030[51] in its long-term commitment to– "ecosystem based fisheries management" and to ensuring that "biodiversity and the function of ecological systems, including trophic linkages, are conserved". While New Zealand's environmental record with regard to fishing is perceived to be relatively high on an international scale, the Ministry is not complacent about the ongoing requirement to monitor and provide evidence that measures to achieve biodiversity conservation needs are being met. This is particularly true of the need to better understand and mitigate the effects of fishing on the areas impacted by fishing.The effects of fishing on the aquatic environment and risks to biodiversity and marine ecosystems are recognised in Fisheries Plans. Research continues to be supported through the Deepwater Research Plan, as well as the Aquatic Environment and Biodiversity Research Programmes.

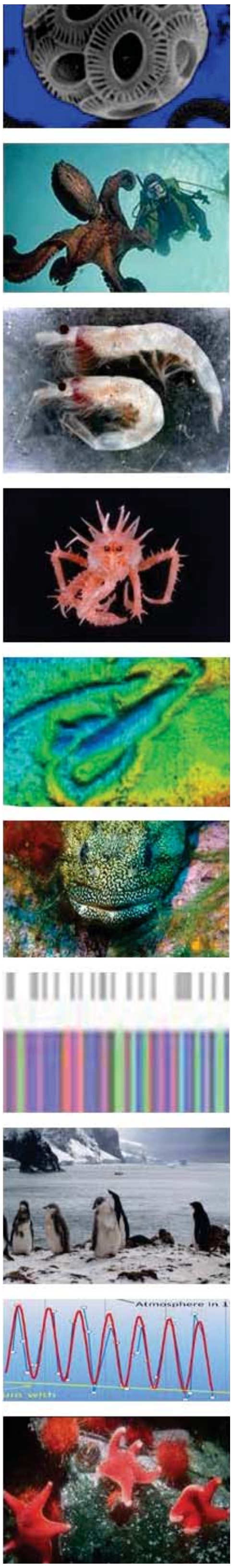
There are also a range of societal values beyond commercial, customary and recreational take from the sea that are recognised as part of "strengthening our society" (see footnote 12). These include aesthetic and cultural values as well as other economic values such as tourism and marine recreation other than fishing[52]. To link socio-economic values of biodiversity to science supporting fisheries management will require a multi-disciplinary approach only just beginning in New Zealand.

MPI responded to the NZBS in 2000 with the establishment of the MPI Biodiversity Programme which has run successfully for more than 10 years with 55 research projects and a large number of published outputs, presentations and contributions to NZ and CCAMLR management measures.

The Ministry is one of several New Zealand government agencies with a strong interest and a statutory management mandate in the Ross Sea region of Antarctica through the Antarctic Marine Living Resources Act 1981. MPI Antarctic science contributes strongly to New Zealand's whole-of-government involvement in contributions to the Commission for the Convention on Antarctic Marine Living Resources (CCAMLR) and the Antarctic Treaty. Research conducted under the MPI Antarctic Biodiversity Programme seeks to help New Zealand deliver on its international obligations to support an ecosystem-based approach to management in Antarctic waters. There are strong links with the MPI Antarctic Working Group research and with other Ross Sea ecosystems research carried out under NIWA core purpose Fisheries, and Coast and Oceans Centres (e.g., Sharp *et al*. 2010).

The biodiversity research programme set up under the NZBS was established with a multi-stakeholder biodiversity research advisory group (BRAG), chaired by the former Ministry of Fisheries (now MPI). The research commissioned for the period 2001–2005 reflected goals set by the NZBS and the BRAG, while remaining compatible with the Ministry of Fisheries Statements of Intent (SOIs). During the first three years of this period, MPI also commissioned marine biosecurity research under NZBS, but this was transferred to Biosecurity New Zealand (MAFBNZ) in 2004. From 2006 to 2010, the programme evolved further with the development of a new 5-year work programme to address shortcomings identified in the review of the NZBS by Clark and Green (2006). An overview of the Biodiversity Programme at a glance is given in Figure 11.4.

[51] Fisheries 2030 The full document can be downloaded from www.fish.govt.nz/en-nz/Fisheries+2030
[52] MARBEF: The Valencia Declaration 2008 www.marbef.org/worldconference



BIODIVERSITY THEMES	KEY QUESTIONS
BIODIVERSITY PATTERNS & DISTRIBUTION • Fauna and flora (taxonomy, biosystematics) • Distribution & abundance of major groups • Reviews of existing knowledge • Biogeography • Drivers of observed patterns	• What is the abundance and distribution of marine biodiversity in NZ? • What are the key drivers of observed patterns in biodiversity? • How much marine endemism is there in NZ waters? • What is the organism size distribution? • How do patterns in biodiversity change over time?
HABITAT DIVERSITY • Biogenic reefs • Rocky reefs • Rhodolith beds • Seamounts • Soft sediments • Habitat mapping EEZ • Deepsea habitats • Physical and biological characterisation	• What are the relative goods and services offered by each habitat to aquatic environment health? • Can the assemblages and biodiversity of marine habitats in the EEZ be predicted by modelling? • Which habitats are at greatest risk from extraction practices? • What proportion of a given habitat needs to remain intact for healthy ecosystem functioning?
FUNCTIONAL DIVERSITY • The role of different animal/plant groups in the ecosystem • Trophic processes • Bentho-pelagic processes	• How does biodiversity contribute to the resilience of ecosystems to perturbation? • Can we use ecosystem function to classify biodiversity? • Which key processes need to be retained?
GENETIC DIVERSITY • Barcode of Life • Connectivity (populations, areas)	• What barriers drive connectivity within species? • What is the role of endemism in characterising the evolutionary history and taxonomy?
THREATS TO BIODIVERSITY • Climate change and variability • Invasive organisms; fishing • Land-use effects • Cumulative effects	• What are the key threats? • Does biodiversity increase resilience to climate change? • Which components of the ecosystem will be most at risk from climate change?
METHODS • Measuring biodiversity • Classification • Predictive modelling • Biodiversity indicators • Monitoring biodiversity • Ecosystem approaches	• How can we best measure and portray biodiversity? • How scalable are results from a local scale to an ecosystem scale? • What do we need to monitor to measure risks and change to ecosystem health? • How can we measure the economic value of biodiversity and ecosystem services?
BIOROSS/ & IPY RESEARCH • Bioross coastal biodiversity • Subtidal ice-sea interface • Census of Antarctic marine Life survey for IPY, Ross Sea • Trophic modelling Ross Sea • Balleny Islands survey for MPA • Functional habitats	• What is the connectivity between biodiversity in the Ross Sea and NZ? • How are biota adapted to polar conditions and what is their sensitivity to perturbation? • Are MPAs a useful protection tool for the Ross Sea? • Are climate change effects on the ocean already impacting on the Ross Sea biota?

Figure 11.4: Summary of MPI Biodiversity Research Programme 2000–2012.

ACHIEVEMENTS & KNOWLEDGE TO DATE	CURRENT WORK
• Taxonomy of coralline algae and bryozoans (2 ID Guides) • New species from surveys added to benthic ID Guides • Review of macroalgae distribution on soft sediments • Contribution to several books on marine biodiversity in NZ • EEZ surveys on Fjordland, Spirit's Bay, Kermadec seamounts, Farewell Spit, Norfolk Ridge, Chatham Rise and Challenger Plateau. • Links to MAFBNZ biodiversity mapping; MEC, MFish BOMEC • Extensive new data sets and specimen collections obtained	• Ongoing taxonomic work in relation to deep sea corals (VMEs) • Ongoing taxonomic work on specimens collected from the Chatham-Challenger project and from the IPY –CAML project.
• Ecological input to improve MEC (fish, benthic invertebrates) • Deep-sea habitats , biogenic habitat and soft-sediment reviewed • Ocean Survey 20/20 habitats mapped Chatham-Challenger • Biodiversity of Kermadec and Chatham Rise seamounts mapped • Foveaux Strait habitats mapped • Classification of seamounts and VMEs developed • Testing of MEC with Chatham Challenger data • Rhodolith beds as havens of biodiversity in NZ	• Mapping biogenic structures • Mapping deepsea fisheries habitats in relation to ocean acidification threats from changing saturation horizons • Modelling benthic impacts
• Rocky reef ecosystem function studied • Chatham Rise fish feeding study completed • Productivity in horse mussel and echinoderm benthic communities determined • Bioindicators in estuarine systems in Otago determined • Chatham-Challenger functional component analysis completed • Shellhash habitat function in the coastal zone	• Ocean acidification on shellfish • Response and recovery of seabed to disturbance-modelling project
• Molecular ID of certain fish and plankton determined • EEZ and Ross Seaspecies added to Barcode of Life Database, • Genetic assessment of ocean microbe diversity • Seamount connectivity reviewed	• Connectivity among coastal fish populations
• Threats and impacts to biodiversity and ecosystem functioning beyond natural environmental variation identified • Monitoring of plankton on transect NZ to Ross Sea annually • Changes in coccolithophore diversity and abundance in NZ waters and predicted change as temp and acidification increase asessed • Long-term effects of climate change on shelf ecosystems determined	• Experimental response of shellfish pH and temp. • CPR monitoring • Initial appraisal for MEMP • Acidification in deepwater fish habitat
• Diversity metrics and other indicators to monitor change developed • Large-scale sampling protocols for habitat mapping determined • Acoustic habitat mapping tools developed • Workshop held on qualitative modelling and marine environment monitoring • Development of "OFOP" and DTIS-visual analytical methods • Predictive modelling techniques progressed for biodiversity on different scales • Development of data to end-user portal interfaced with NABIS	• Development of functional biota model for habitat classification • Qualitative and quantitative modelling of rocky reef ecosystem • Predictive modelling VMEs • Measuring risk and resilience (Chat-Chall objective)
• Latitudinal gradient project and ICECUBE completed in Ross sea • Fish taxonomy and ID guide developed for the Ross Sea • Foodweb and role of silverfish vs krill studied • IPY-CAML 2008; Ross Sea 2006, BioRoss 2004 surveys done • Subtidal and offshore biodiversity sampled, Balleny Islands 2006 • Seaweed diversity determined at Balleny Islands • Bioregionalisation of the Ross Sea region completed	• finalisation IPY analyses • Uptake of biodiversity results to CCAMLR trophic modelling and biomass estimation, VMEs • New spp logged for CAML • Review of squids, octopus

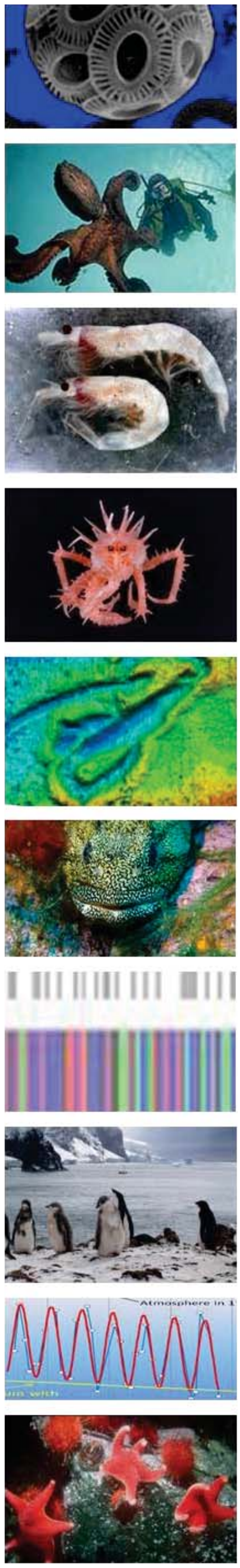


Figure 11.4: ***Continued*** **Summary of MPI Biodiversity Research Programme 2000–2012.**