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Development of a National Marine Environment Monitoring Programme (MEMP) for New Zealand

New Zealand Aquatic Environment and Biodiversity Report No. 141

J.E. Hewitt

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Long-term environmental monitoring is key to documenting trends in environmental status and can be an important management tool, providing feedback on the efficacy of specific management actions and policies. Marine environmental monitoring is currently carried out in an *ad hoc* fashion across the country and does not allow for ready analysis or reporting of long-term trends in New Zealand waters. This study was commissioned to review current levels of marine environmental monitoring, and evaluate the possibility of developing a comprehensive long-term marine environmental monitoring programme for New Zealand's marine environment (including oceans, coasts and estuaries) from existing sampling programmes.

The study had four components: 1 the development of an online meta-data catalogue of existing marine environmental monitoring programmes in New Zealand; 2 an evaluation of which datasets could best be used to detect long-term trends in the state of our marine environment at a national scale; 3 recommendations on a robust monitoring design focused around present monitoring; and 4 propose improvements to data collection, analysis and storage to provide greater cohesion for marine environmental reporting at the national scale.

In all, 136 databases were identified, with most holding data for more than one location. Half of these are listed as having ongoing funding and over 60% are in the public domain. More than half of the databases record data collection over more than 10 years. The meta-data catalogue is stored online and can be accessed at http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand.

Variables potentially suitable for monitoring and reporting on the state of New Zealand's marine environment at a national scale were identified from recent local and central government policy and strategic documents. Thirty-five variables (biological, physical and chemical from both the seafloor and the water) were examined in detail for their fitness for purpose for national monitoring by considering what each could be used to report on, what was known about their degree of response to individual stressors, the degree of natural temporal variability; the present spatial and temporal coverage of monitoring; and whether consistent standard methods are used.

In accordance with many international programmes emphasis is placed on data collected over a range of spatial and temporal scales, from continuous coverage through to point measures. Continuous coverage, such as is frequently provided by satellite for ocean temperature, is extremely useful for any national level reporting. Unfortunately, the number and type of variables for which information can be collected in this way is restricted and direct (usually at a single point often at a single time) is required to extend these basic measures. When these more restricted measures are made it is important that there is some generality of spatial coverage, e.g., measures in the north, east, south and west, unless the positions sampled target a location that has been chosen either as representative of general New Zealand conditions, or as a first point of change.

Data on sea level height and sea-surface temperature are available across the Exclusive Economic Zone from remote sensed data. Remote colour data from which sea-surface chlorophyll-a is

calculated are also available over this area. These data relate primarily to assessing climate change, although chlorophyll-a is also used as a proxy for primary productivity in surface waters. Estimations of the extent and density of suspended sediment plumes in nearshore areas can also be made from remote sensed colour data, but would require regional validation of algorithms.

Macroinvertebrate (community and biodiversity) information and sediment characteristics (such as mud content, metal contamination and nutrient concentrations) are collected on a regular basis from many estuaries and harbours around the country. These data relate both to major stressors on our estuarine and harbour systems, and responses to those stressors. The data can be used to assess their health, functioning, integrity and the ecosystem services that they produce, as well as how these may change as a result of climate change and many land- and marine-based activities.

Information on biodiversity, size structure and the trophic dynamics of demersal fish communities in some of our major fishing areas are also available. While these data can not be used as a surrogate for diversity of other components of these ecosystems, the data is an essential component of any assessment of health, functioning, integrity and ecosystem services.

Reporting on any of these variables at a national level would, however, require development of an analytical and reporting regime. Most variables would also require some extension of data collection, analytical methodological research and technique validation to be fully robust.

At this stage, insufficient data are being collected on water chemistry, water column biodiversity (excluding demersal fish), coastal ecological communities, and broad-scale habitats for these to be robustly reported on at a national scale. In some cases, methods for improving the collection of such data are under development (e.g., remote assessment of nutrients and habitats). In other cases, the strategies for data collection are under development (e.g., effective monitoring strategies for water quality and acidification are presently under investigation in New Zealand, in conjunction with international efforts (such as Australia's Integrated Marine Observing System, Monterey Bay Aquarium Research Institute, Global Ocean Acidification Observing Network).

Monitoring all potential variables at a national scale would be cost-prohibitive at present and research to determine new cost-effective measures that provide a wide range of information will be key to national-level reporting of the status of New Zealand’s marine environment. Such research is ongoing in a number of areas and this report has been seen as critical to focussing attention on specific knowledge gaps.

2 INTRODUCTION

2.1 Monitoring rationale

New Zealand's marine environment is one of the largest in the world, containing 441 estuaries, about 18 000 km of coastline and a sea floor area over 20 times the size of its land mass. At the time of writing, no acts (see Appendix 1 for Acts related to the marine environment) or policy statements explicitly require monitoring of the marine environment. However, government agencies acknowledge that reporting on many of the objectives and goals contained within acts and policies can only occur if monitoring takes place. For example, the New Zealand Coastal Policy Statement 2010 "Policy 22 requires control of activities to prevent a significant increase in sedimentation in the coastal marine area", the success of which can only been determined by monitoring of sedimentation over time. Many international treaties (e.g., United Nations Law of the Sea, Convention on Biodiversity) also require provision of information over time to show that obligations are being (and continue to be) met.

Monitoring programmes are conducted for a number of reasons, including monitoring to determine policy success, the efficacy of management actions, impacts, the extent or concentration of pollutants, and environmental health. These types of monitoring are usually designed to address specific questions, or assess cause and effect, and are often spatially limited. However, much of the monitoring that is conducted both within New Zealand and internationally is conducted to determine the overall health or the state (status) of the environment (SOE monitoring), and to identify long-term trends in a mix of ecological, physical and chemical variables. Such monitoring is not focused on answering specific questions. Rather it is accepted that multiple factors (anthropogenic activities and naturally changing environmental conditions) will be affecting what is monitored. Identification of change in the state of the environment above natural variability and whether the direction of such change is acceptable to society as a whole (i.e., economically and culturally) is of primary importance.

While it sounds as if monitoring would be more useful if more specific questions were asked and monitoring were tied very closely to measurement of cause and effect variables, this approach is problematic for a number of reasons. Firstly, only the effect of that specific cause can be assessed. Secondly, society's wants and needs are not static, instead they continuously change, thus, the questions asked in the present are not necessarily those that require answering in the future. SOE monitoring, while sounding inefficient, generally is more future proof than other types.

In reality, a mix of specific and integrated environmental variables is required for environmental monitoring. If the SOE monitoring is sufficiently broad based, identification of causes can be achieved, by analysis of changes or lack of changes in a wide range of factors that reveal a pattern which can be scientifically interpreted. Specific research or data collection programmes can be designed to isolate the cause of change, or most likely, the set of causes.

2.2 Background to marine environmental monitoring in New Zealand

Over the last few years there have been a number of central and local government initiatives related to monitoring of the marine environment.

The Ministry for Primary Industries (MPI) (formerly Ministry of Fisheries) monitors catch levels and the relative abundance of commercial fish stocks under the Fisheries Act 1996. The Fisheries Act 1996 also requires MPI to take into account the broader impacts of fishing (e.g., "Avoid, remedy, or mitigate any adverse effects of fishing on the aquatic environment (s8(2)), "Biological diversity of the aquatic environment should be maintained (s9(b))". Under this remit MPI has funded research investigating the potential of ecosystem indicators from trawl surveys and fish-stock indices (Dunn et al. 2009, Tuck et al. 2009). A review of ecosystem indicators of specific relevance to deepwater fisheries is currently underway within MPI project DEE2010-05A. MPI also held a multi-stakeholder workshop in 2008 under the auspices of the MPI Marine Biodiversity programme to examine options for marine Environmental Monitoring at a national scale. It is this group, collectively with MfE, that resulted in the current project being undertaken.

Over the last decade, Biosecurity New Zealand (now MPI Biosecurity) has fully developed the Marine High Risk Site Surveillance programme and accompanying database. Monitoring of non-indigenous species is conducted every six months in 11 harbours that are first entry for international vessels. The Marine Invasives Taxonomic Service has also been developed. Information is collected on national distribution and relative abundance of known non-indigenous species, as well as detection of new incursions.

The Department of Conversation (DOC) has been working towards two main goals related to monitoring the marine environment: methods for identifying values and risks to those values; and standardising reporting across their areas of responsibility (terrestrial, freshwater and marine territorial sea). DOC has identified the concept of ecological integrity as the basis on which to assess state of the environment. Ecological or ecosystem or biological integrity is a term, used in many international assessments, that encompasses the functionality and self-maintenance of an ecosystem (Burkhard et al. 2011). Lee et al. (2005), referring to a report from The United States National Academy of Sciences (2000), defined integrity as: "The capacity to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species, and assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) expected in the natural habitat of a region". In New Zealand ecological integrity is based on the assessment of four themes: nativeness, pristineness, diversity and resilience; variables that may be included in its measurement are given in Thrush et al. (2012). DOC has also reviewed the monitoring programmes conducted in marine reserves (Tam 2013), to improve consistency and comparability of design and enable national reporting on the status of, and the trends occurring in, New Zealand's marine reserves, and are validating cost-effective monitoring methods for integrity (e.g., Hewitt et al. 2014).

The Ministry for the Environment ((MfE) series of workshops in 2009 (Environmental Monitoring Forums), while mainly devoted to freshwater included some discussion on the marine environment and highlighted the need for a more co-ordinated approach in both marine and freshwaters (http://www.mfe.govt.nz/publications-/ser/environmental-indicators/issue-06-spring-2009/index.html). Ongoing work with DOC involves developing objectives and limits for estuarine health as part of the National Objectives Framework (NOF) under the National Policy Statement on Freshwater Management. In 2010 and 2011, MfE produced guidelines for matters to be considered in selecting indicators and has highlighted the use of the Pressure-State-Response framework for environmental monitoring. To aid the use of this framework, both MfE and MPI have funded work on anthropogenic stressors that already, or are likely to in future, exert pressure on the New Zealand marine environment (MacDiarmid et al. 2012a (MPI funded), Ministry for the Environment 2007). MacDiarmid et al. (2012a) identified 65 stressors and, based on accumulated expert opinion, ranked them by the severity of their likely impact and the number of habitats that they could impact. The top ten threats to the marine environment were: ocean acidification, climate change, fishing, increased sediment loading and turbidity, invasive species, dumping of dredged sediment, algal blooms, reclamation, pollution from urban sources and aquaculture. The number of threats to marine habitats declined with depth, with sheltered and exposed coastal areas identified as being substantially more at risk than open water areas.

Statistics New Zealand in conjunction with MfE, MPI and DOC have recently developed an environment domain plan (EDP) to improve the official environmental statistics reported (Statistics New Zealand et al. 2013). The overarching question identified for the marine domain was "How is the quality and use of our marine environment changing and what is the impact of human activity, including resource use, on the marine environment?". Of the six supplementary questions, three related to identifying changes over time in the marine environment. Terms specifically mentioned in the EDP include "Ecosystem services" (see Appendix 2 for definitions), "Resilience" and "Impact of human activities”. Climate change was also highlighted by the EDP with physical impacts on sea temperature, sea level and ocean currents specifically mentioned. Other questions included enduring question 4 “which environments are most likely to be affected by climate change?” and supplementary question D “where and how are ecosystems-------- most affected by changes to climate and atmospheric composition, and how are they adapting?”

A number of regional councils and unitary[1] authorities have State of the Environment (SOE) monitoring programmes (e.g., Northland Regional Council SOE Water Quality Monitoring, Otago Regional Council Estuary monitoring programme). Recent efforts have focused on reporting and summarising techniques to explain and help the public fully understand the meaning and causes of any changes in state observed. This includes development of guidelines and limits for specific stressors (Greater Wellington Regional Council; Green 2013), indicators of ecosystem health (Auckland Council, Anderson et al. 2006) and models to relate changes in health of intertidal sandflats with storm water contamination and sedimentation (Hewitt et al. 2009, Rodil et al. 2013). In particular, Auckland Council and Waikato Regional Council, in conjunction with DOC, have been investigating the use of ecosystem goods and services in both spatial planning and monitoring, as being essential for both in bringing human values into planning decisions and in helping communities assess the importance of any changes revealed by monitoring.

The National Institute of Water and Atmospheric Research (NIWA) has been conducting research on methods for remotely assessing the sea-surface environment and for measuring resilience and ecosystem health. A method for mapping marine ecosystem goods and services based on merging readily obtainable physical, chemical and biological measurements with ecological first principles (Townsend et al. 2011) has been developed and is being trialled in the Hauraki Gulf. Further research on this methodology .is being conducted in conjunction with a Ministry of Business, Innovation and Employment (MBIE) smart idea run by Massey University and Cawthron. NIWA has also begun to analyse its long-term marine datasets to identify temporal variability and identify whether causes of variability can be identified.

Finally, the first meeting of scientists to discuss priorities for the Science Challenge “Life in a changing ocean” (24th June, 2013, MBIE, Wellington) identified by general consensus that marine environmental monitoring is a major knowledge gap and should be considered for inclusion in any programme funded under the Challenge http://www.msi.govt.nz/assets/Update-me/National-Science-Challenges/Workshops-/Workshop-outputs-Life-in-a-Changing-Ocean-18-June-2013.PDF.

2.3 International monitoring effort.

Practices for monitoring the marine environment outside New Zealand vary in scale and the variables measured. Most current international-scale programmes (e.g., Global Ocean Observing System (GOOS) and the Integrated Ocean Observing System (IOOS)) have focused primarily on physical and chemical measurements in the open-ocean (and some exposed outer coast) sites, increasingly with automated sensors. However, a recent US initiative for international monitoring (e.g., Smithsonian Institution monitoring of coastal biodiversity http://newsdesk.si.edu/releases/smithsonian-launches-global-marine-biodiversity-project-10-million-donation, MARINEGEO – integrated ecological observatories for changing marine ecosystems) is focused more on estuaries and near-shore regions declaring them to be “regions where ecological changes are arguably the greatest and most rapid”, possibly due to the large number, and high intensity, or stressors often found in these regions.

National-scale SOE monitoring overseas is frequently based around key species, significant habitats and indices of sediment, water and benthic ecological health. In Europe, the recently developed Marine

[1] A territorial authority (district or city) which also performs the functions of a regional council. New Zealand has five unitary authorities: Gisborne District, Nelson City, Tasman District, Marlborough District, and the new Auckland Council.

Strategy Framework Directive (MSFD) which defines the framework for individual nations monitoring, uses as an overarching principle "good environmental status" (http://ec.europa.eu/environment/-water/marine/ges.htm; http://ec.europa.eu/environment/indicators/index_en.htm). In summary, this covers provision of ecologically diverse systems, clean, healthy and productive systems, sustainable use preserving the structure, functions and processes of the systems, allowing them to function fully and to maintain their resilience. Within this framework are nested measurements of biological diversity, non-indigenous species, populations of commercial fish / shellfish, marine food webs, sea floor integrity, contaminants, litter, and noise and indicators such as B-IBI (US), AZTI's Marine Biotic Index (AMBI and its multivariate equivalent (M-AMBI)) and the Benthic Quality Index. Most of these indicators are used in more than one country. M-AMBI, developed for European conditions, is being trialled for use in the US by the EPA as an alternative to regionally developed indices and has also been tested for use in New Zealand (Rodil et al. 2013).

2.4 Projective Objectives

The overall objective of this project was to design a national Marine Environment Monitoring Programme (MEMP) that could track the physical, chemical and biological changes taking place across New Zealand's marine environment over the long term. Four objectives were included:

1. To prepare an online inventory (meta-database) of repeated (time series) biological and abiotic marine observations/datasets in New Zealand (see Section 3).
2. To review, evaluate fitness for purpose and identify gaps in the utility and interoperability of these datasets for inclusion in MEMP from both science and policy perspectives (see Section 4).
3. To design a MEMP that includes relevant existing data collection and proposed new time series (see Sections 5 and 6).
4. To suggest improvements to data collection and data management regimes (see Sections 7 and 9).

The definition of the marine environment used within this project is consistent with that of Statistics New Zealand et al. (2013), which includes physical, chemical and biological aspects of seas and oceans, harbours, river estuaries, salt-water marshes and mangroves and coasts and beaches. For this report, "estuary" refers to all estuarine types covered by the estuarine classification database (Hume & Herdendorf 1988, http://wrenz.niwa.co.nz/webmodel/coastal) and includes estuaries, harbours, sounds and fiords.

3 ONLINE META-DATA CATALOGUE

At the time that this project was initiated, no single repository listing high level information on what marine monitoring data existed in New Zealand. The first objective of the project was to identify marine environmental datasets that formed a time series (i.e. could be classed as monitoring) currently being collected in New Zealand, and develop an online catalogue of high level information (meta-data) about the datasets so that the extent and nature of marine environmental monitoring taking place could be assessed for its utility for national monitoring and reporting on the marine environment.

3.1 Development of the online meta-data catalogue

Requirements for a useful metadata catalogue relate to ease of use (easy to discover, search, enter new data into and maintain), richness of information (allowing searchers to decide whether data are fit for their purpose and to find out how to gain access to the data); and adherence to standard protocols and vocabularies. Within New Zealand, many metadata catalogues use ANZLIC (Australia New Zealand Land Information Core) or MCP (Marine Communities Profile). For the metadata catalogue underlying the MEMP, standardisation was considered especially important as the ability to exchange information with international databases such as GBIF (Global Biodiversity Information Facility), OBIS (Ocean Biogeographic Information System) and WoRMS (World Register of Marine Species) was recognised as critical.

Today, the trend is towards federated catalogues with portals designed to harvest specialities by accessing catalogues held by a number of organisations. This structure for MEMP (a federated catalogue based on MCP standards was presented as an option to stakeholders (see Appendix 3) and this approach was adopted for the MEMP online catalogue.

3.2 Available time series data

Questionnaires were developed to determine what marine environmental time series data are available within New Zealand. They were sent out to 39 key stakeholders (Appendix 4) and posted on the New Zealand Marine Sciences webpage. All correspondents were invited to forward the questionnaire on to other potentially interested people.

An initial vetting procedure of submitted datasets was developed using criteria to determine: whether the dataset formed a time series (at least three repeated measures at the same location at least one year apart); was reliable (some form of quality assurance and standardised, recorded methods); and was available for potential use in a national monitoring programme (see Appendix 5 for a full list of requirements).

Organisations with harvestable online meta-data catalogues (NIWA, DOC, Auckland Council) were asked to place the word “MEMP” in the “usage” field of relevant data entries. Meta-data not held in such catalogues were hand entered into the MEMP meta-data catalogue.

3.3 The online meta-data catalogue

The MEMP online catalogue for New Zealand is a federated system (see http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand) that uses the Marine Communities Profile (MCP) protocol. Table 1 gives the fields utilised by the MEMP catalogue.

Table 1: Information requirements of the MEMP meta-data catalogue derived from a questionnaire of data users and suppliers and the need to conform to international databases. * = Required information.

Field Name	Example of information requirements
*Title	Name of dataset
Reference Date	Date last updated
Reference Date Type	Type of updating
*Language	English
*Topic	Description of what data is held in the database
Citation	How would the database be cited
*Abstract	Measured and derived variables including methods, number of locations, extent of location and number of replicates, temporal resolution, frequency, completeness and number of records
*Keywords	marine, estuarine, beach, coastal, ocean, coastal, water column, benthic hard, benthic soft, seamount, ecological, chemistry, physical, trawl, grab, visual observation, video, photograph, multibeam, satellite, aerial photography, core, dredge, CTD, buoy, trap, other
*Purpose	Why was the data collected
Credit	Recognition of those who contributed to the dataset
Data Quality Lineage	General explanation about the events or source data used in constructing the dataset
Quality assurance	Type of quality assurance used
Funding status	Finished or ongoing
Limitation to use	Limitation affecting the fitness for use of the dataset
*Access Constraints	Access constraint applied to assure protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource
*Use Constraints	Constraint applied to assure protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource
Other Constraints	Any other constraints
*Contact Person details	Person to contact to use
*Meta data Person details	Person who maintains data
Online Resource details	URL for online access to the dataset, Description of the online resource, Name of the data transfer format,Version of the format
*Meta-data File Identifier	Unique identifier for this metadata file
*Meta-data Standard Name	Marine Community Profile of ISO 19115 Version 1.4
*Geographic Description	Description of spatial area
*Spatial Representation	Method used to spatially represent geographic information
*Geographic Reference	Reference system for geographic information in the dataset. e.g. NZMG
*Geographic Reference Authority	Authority for the Geographic information reference system. e.g. LINZ
*Vertical Minimum	Lowest vertical extent in the dataset
*Vertical Maximum	Highest vertical extent in the dataset
*Unit of Measurement	Units used for the vertical extent values
*Vertical Origin	The origin from which the maximum and minimum values are measured
*Start Date	Date of first sample in database
*End Date	Date of last sampling if over
*Temporal Reference	Reference system for temporal information in the dataset. E.g. NZST/NZDT
Spatial resolution	Pixel size and unit of measurement, etc for gridded data

The project identified 136 databases (Table 2) currently available in New Zealand that fit the temporal criteria as a time series and for use in a potential Marine Environmental Monitoring Programme. Half of these are listed as having ongoing funding (although not necessarily for all locations) and another 19% are listed as likely to continue. Over 60% are publically available. Most cover more than one location, although this is dependent on how the databases are constructed, e.g., DOC at present has a separate database for each marine reserve, while regional councils tend to have separate databases for different subjects (e.g., contaminant monitoring, ecological monitoring).

Table 2: List of databases[2] containing time-series data relevant to the marine environment that have data collected on at least three occasions in the same location, over at least a three year time period. For large spatial scales (e.g., remote sensed data), the location type is given as Territorial Sea, EEZ, Nationwide (if only the coastal part of the Territorial Sea is sampled) or Regionwide if only a portion of the Territorial Sea or EEZ is sampled. For sampling over smaller scales, location types are estuary (as per New Zealand's Estuarine Classification and includes harbours), coastal and ports and offshore. Some locations were labelled as "controls" as they were part of a impact monitoring scheme. Length of time is the time since the first sampling and may not include all sites or all variables if the programme has altered over time.

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Sea Level Database	Antarctic NZ	1 estuary	sea level	>10	public
Benthic Health Programme	Auckland Council	3 estuaries	infauna, epifauna	>10	public
Marine Ecology - Estuaries	Auckland Council	8 estuaries	sediment (grainsize, organics, accumulation rate), epifauna, infauna	>10	public
Marine Ecology - Harbours	Auckland Council	5 estuaries	sediment (grainsize, organics, chlorophyll-a), epifauna, infauna	>10	public
Marine Ecology - Rocky Reefs	Auckland Council	8 coastal	epifauna	>10	public
Regional Sediment Contaminant Monitoring Programme	Auckland Council	9 estuaries	sediment (nickel, cadmium, chlorophyll-a, sediment grainsize, lead, zinc, chromium, copper, arsenic, organics)	>10	public
Saline WQ Monitoring - Regional Status And Trends	Auckland Council	4 estuaries, 9 coastal	water (salinity, oxygen, conductivity, temperature, pH, enterococci, dissolved reactive phosphate, total phosphorus, total kjeldahl nitrogen, total nitrogen, nitrate, nitrite, nitrate + nitrite, chlorophyll-a, chloride, turbidity,	>10	public

[2] This list is not exhaustive, even at the time of this report. It contains all national databases with time series data (or meta-data) that were discovered during the project. It does not include data held in international databases such as ARGO (see www.argo.ucsd.edu) or the Continuous Plankton Recording data (held by the Australian Antarctic Division), although these data will be discussed later on in Sections 4 and 6).

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
			suspended solids, ammoniacal-n (nh_4), total oxidisable inorganic nitrogen)		
Sentinel Shellfish Contaminant Monitoring Programme	Auckland Council	2 estuaries	tissue (metals, organics), depth	>10	public
Marine Ecology - Tier II Habitats and Communities	Auckland Council	3 estuaries, 2 coastal	infauna, epifauna, macroalgae, rocky reef, soft-sediments, intertidal, subtidal, sediment grainsize	to 10	public
Maritime Wetland Mapping	Bay of Plenty Regional Council	regionwide	estuarine vegetation and habitat mapping	>10	restricted
Seagrass and Mangrove Mapping	Bay of Plenty Regional Council	regionwide	estuarine vegetation and habitat mapping	>10	restricted
Sea Level Database	Bureau of Meteorology-Australia	1 coastal	sea level	>10	public
Kahukura (Gold Arm)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public
Kutu Parera (Gaer Arm)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public
Long Bay-Okura	DOC	1 estuary	intertidal and subtidal reef benthic communities and key species	>10	public
Moana Uta (Wet Jacket Arm)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public
Parininihi	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Piopiotahi (Milford Sound)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public
Pohatu (Flea Bay)	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species	>10	public
Taumoana (Five Finger Peninsula)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public
Te Angiangi	DOC	1 coastal	intertidal benthic reef communities; subtidal rocky reef fish; rock lobster	>10	public
Te Tapuwae O Hua (Long Sound)	DOC	1 estuary	subtidal reef benthic communities and key species (abundance and population size structure of mobile invertebrates, sessile invertebrates, algal communities and other selected key species (e.g. paua, kina)); subtidal rocky reef fish; rock lobster	>10	public
Te Tapuwae O Rongokako	DOC	1 coastal	intertidal benthic reef communities; subtidal rocky reef fish; rock lobster	>10	public
Tonga Island	DOC	1 coastal	intertidal benthic reef communities; subtidal soft sediment benthic communities; subtidal reef benthic communities and key species; reef fish species; rock lobster and blue cod	>10	public
Ulva Island - Te Wharawhara	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	>10	public
Cape Rodney-Okakari Point	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species; rock lobster	to 10	public
Hawea (Clio Rocks)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	to 10	public
Horoirangi Marine Reserve	DOC	1 coastal	intertidal reef communities; subtidal soft sediment benthic communities; subtidal reef benthic communities and key species; rocky reef fish; rock	to 10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
			lobster and blue cod		
Kapiti Island	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species; rock lobster	to 10	public
Long Island−Kokomohua	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster; blue cod	to 10	public
Motu-Manawa-Pollen Island	DOC	1 estuary	intertidal soft sediment benthic communities	to 10	public
Poor Knights Islands	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species; rock lobster	to 10	public
Taipari Roa (Elizabeth Island)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species; rock lobster	to 10	public
Te Awaatu Channel (The Gut)	DOC	1 estuary	subtidal reef fish, reef rock lobster	to 10	public
Te Hapua (Sutherland Sound)	DOC	1 estuary	subtidal reef benthic communities and key species, reef fish species	to 10	public
Te Matuku	DOC	1 estuary	subtidal estuarine demersal fish species and intertidal soft sediment benthic communities	to 10	public
Te Paepae O Aotea (Volkner Rocks)	DOC	1 coastal/ocean	subtidal reef benthic communities and key species	to 10	public
Tuhua (Mayor Island)	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species; rock lobster	to 10	public
Whanganui A Hei	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species; rock	to 10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
(Cathedral Cove)			lobster		
Taputeranga	DOC	1 coastal	subtidal reef benthic communities and key species, reef fish species		public
Bay of Plenty Coastal and Estuarine Soft Shore Monitoring Programme	Environment Bay of Plenty	4 estuaries	infauna, epifauna	> 10	public
Bay of Plenty Water Quality	Environment Bay of Plenty	30 coastal	water (salinity, oxygen, conductivity, temperature, pH, *E. coli*, enterococci, faecal coliforms, dissolved reactive phosphate, total phosphorus, total nitrogen (total nitrogen), nitrate + nitrite (nnn), ammoniacal-n, chlorophyll-a, turbidity, suspended solids, black disk, depth)	>10	public
Bay of Plenty Marine Sediment Contaminants	Environment Bay of Plenty	2 estuaries	sediment (nickel, cadmium, grainsize, lead, zinc, chromium, copper, arsenic, organics, total organic carbon)	to10	public
Bay of Plenty Coastal And Estuarine Rocky Shore Monitoring Programme	Environment Bay of Plenty	unknown coastal	epifauna	>10	restricted
Intertidal Soft Sediment Monitoring	Environment Canterbury	5 estuaries	sediment (nickel, cadmium, redox, ash-free dry weight, grainsize, lead, zinc, chromium, copper, arsenic, organics, mercury), infauna, epifauna	<5	public
Avon-Heathcote Estuary - Healthy Rivers and Estuary of the City Programme	Environment Canterbury	1 estuary	water (salinity, oxygen, temperature, pH, *E. coli*, enterococci, faecal coliforms, dissolved reactive phosphate, total phosphorus, total nitrogen, nitrate + nitrite, ammoniacal-n, chlorophyll-a, turbidity, suspended solids), sediment (metals, nickel, cadmium, phosphorus, nitrogen, chlorophyll-a, redox, ash-free dry weight, sediment grainsize, lead, zinc, chromium, copper, arsenic), infauna, epifauna	to10	public
Region Wide Coastal Water Quality	Environment Canterbury	32 coastal	water (salinity, oxygen, temperature, pH, dissolved reactive phosphate, total phosphorus, total nitrogen, nitrate + nitrite, ammoniacal-n,	to10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Monitoring			chlorophyll-a, turbidity, suspended solids)		
Intertidal (Sandy) Beach Benthic Assessments	Environment Southland	2 coastal	beach infauna	<5	public
Environment Southland Estuary Health Monitoring Programme	Environment Southland	9 estuaries	sediment(nickel, cadmium, phosphorus, nitrogen, redox, ash-free dry weight, grainsize, lead, zinc, chromium, copper), infauna, epifauna	to10	public
SOE Coastal Water Quality Programme	Environment Southland	2 estuaries	water (salinity, oxygen, conductivity, temperature, enterococci, faecal coliforms, dissolved reactive phosphate, total phosphorus, total nitrogen, nitrate + nitrite, ammoniacal-n, chlorophyll-a, suspended solids, secchi, depth)	<5	restricted
Estuarine Habitat Mapping	Environment Southland	regionwide	broad-scale habitat (vegetation and substrate types)	>10	restricted
Marine Water Quality Monitoring	Gisborne District Council	21 coastal	water (temperature, pH, *E-coli*, total coliforms, enterococci, faecal coliforms, total kjeldahl nitrogen), total nitrogen, suspended solids, metals, bod, cod)	>10	public
Benthic Monitoring	Gisborne District Council	control sites	infauna	>10	restricted
Geonet Tsunami Gauge Network	GNS	17 coastal and offshore islands	sea level	>10	restricted
Spat Monitoring In Golden Bay & Tasman Bay	Golden Bay and Tasman Bay	2 coastal	mussel spat	to10	restricted
Sandy Beach	Greater	1 coastal	beach infauna	<5	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Monitoring	Wellington				
Recreational Water Quality	Greater Wellington	74 coastal, 1 estuary	water (temperature, *E. coli*, enterococci, faecal coliforms, turbidity)	>10	public
Estuary Monitoring Programme	Greater Wellington	4 estuaries	sediment (nickel, cadmium, phosphorus, nitrogen, redox, ash-free dry weight, total organic carbon, grainsize, lead, zinc, chromium, copper, organics), infauna, epifauna	to 10	public
Harbour Sediment Contaminants Programme	Greater Wellington	2 estuaries	sediment (nickel, cadmium, grainsize, lead, zinc, chromium, copper, arsenic, total organic carbon), infauna	to 10	public
Coastal Water Quality	Greater Wellington	2 estuaries	water (salinity, oxygen, conductivity, temperature, pH, *E-coli*, enterococci, faecal coliforms, dissolved reactive phosphate, total phosphorus, total kjeldahl nitrogen, total nitrogen, nitrate, nitrite, nitrate + nitrite, ammoniacal-n, chlorophyll-a, turbidity, suspended solids)	<5	restricted
Estuarine Habitat Mapping	Greater Wellington	regionwide	estuarine vegetation and habitat mapping,	to 10	restricted
Recreational Water Quality	Hawke's Bay Regional Council	25 coastal	water (conductivity, temperature, enterococci, faecal coliforms, turbidity)	>10	public
Estuarine Ecology Monitoring Programme	Hawke's Bay Regional Council	2 estuaries	sediment (nickel, cadmium, phosphorus, nitrogen, chlorophyll-a, redox, ash-free dry weight, grainsize, lead, zinc, chromium, copper, arsenic, organics), epifauna, infauna	to 10	public
Sandy Beach Monitoring	Hawke's Bay Regional Council	6 coastal	infauna	to 10	public
Nearshore Coastal Water Quality	Hawke's Bay Regional Council	1 estuary, 10 coastal	water (oxygen, conductivity, temperature, pH, enterococci, dissolved reactive phosphate, total phosphorus, total kjeldahl nitrogen total nitrogen, nitrate, nitrite, nitrate + nitrite, ammoniacal-n, chlorophyll-a, turbidity,	to10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
			suspended solids, depth)		
Intertidal Reef Monitoring	Hawke's Bay Regional Council	2 coastal	epifauna	< 5	restricted
Seawater Nutrients	Hurd, UoO	2 coastal	water (nitrate, ammoniacal-n, phosphate)	>10	restricted
King Salmon Annual Monitoring	King Salmon Limited	2 estuaries	water (nutrients {nitrate-n, nitrite-n, ammoniacal-n and dissolved reactive phosphorous}, near-bottom organic matter oxygen), sediment (total free sulphides, redox, grainsize, ash-free dry weight, odour, metals {copper, zinc}), bacterial mat coverage, sediment outgassing, infauna, epifauna	<5	public
Sea Level Database	Lyttelton Port Company	1 port	sea level	>10	public
Lyttleton Dredge Spoil Monitoring	Lyttelton Port Company (LPC)	1 estuary	water (salinity, temperature, DO, secchi), faunal tissue (organotins, svocs, trace metals), sediment (grainsize, organic content, svocs, organotins, aliphatic hydrocarbons, trace metals), infauna, intertidal survey (substrate characteristics, zonation patterns), epifauna, macroalgae	>10	restricted
Recreational Bathing Water Quality Monitoring (Includes Freshwater And Coastal Water)	Marlborough District Council	21 coastal	water (salinity, conductivity, temperature, enterococci)	>10	public
Picton Outfall Monitoring Surveys	Marlborough District Council	1 estuary	sediment (grain-size, ash-free dry weight, total organic carbon, total nitrogen, total kjeldahl nitrogen, c and n stable isotope analyses), infauna	>10	restricted
Physical and Biological Monitoring in Doubtful Sound	Meridian Energy Limited	2 estuaries	water (salinity (at 2 or 10 depths), temperature (at 10 depths)), sediment (grainsize, ash-free dry weight), invertebrates, indicator species (cnemidocarpa sp., brachiopods, black coral) abundances, echinoderm abundances, infauna, cockles and pipi size frequency.	>10	restricted

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Acoustic Database	MPI Research Data Manager	EEZ	relative biomass of hoki, hake, smooth and black oreos, orange roughy, and southern blue whiting.	>10	restricted
Beach	MPI Research Data Manager	variable	abundance and size structure of shellfish (toheroa, cockles, *macomona liliana*, pipi, tuatua) and density of sea lettuce.	>10	restricted
CTD (Fisheries Oceanography)	MPI Research Data Manager	EEZ	water (conductivity, temperature, depth)	>10	restricted
Fish Catch Effort	MPI Research Data Manager	EEZ	catch weight, fishing method, fishing locations, vessel ID and fisher ID	>10	restricted
Non Fish Bycatch	MPI Research Data Manager	EEZ	fishing method [in use at the time of non-fish bycatch capture], target species [being fished at the time], date, time, location (latitude/longitude), non-fish bycatch species [e.g. marine mammals, seabirds]	>10	restricted
Rlcs (A) Catch Sampling Schema	MPI Research Data Manager	nationwide	number of rock lobsters caught (both dead and alive) pot type, depth, soak time, bait and an escape gap code, biological data for individual rock lobsters recorded on the length frequency form which includes sex, carapace length, and tail width (across the spines on the second abdominal segment), tail length, weight, injuries, moult and run states, and the red rock lobsters status as to whether it was landed to a licensed fish receiver (LFR)	>10	restricted
Scallop	MPI Research Data Manager	nationwide	commercial scallop catch data	>10	restricted
Squ_CE	MPI Research Data Manager	EEZ	commercial squid fishery catch and effort data, for both commercial species (*Nototodarus gouldi* & *N. sloanii*). including sea temperature, depth, location, fishing method, fishing vessel, date, catch weight, species, trawl speed, trawl time, location	>10	restricted
Trawl	MPI Research Data Manager	EEZ	including sea temperature, depth, location, fishing vessel, date, catch weight, species, trawl speed, trawl time, weight of each fish species caught, for selected species fish, length, sex and age data, camera deployments,	>10	restricted

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
			CTD probes, plankton, physical measurements, blue cod potting.		
Tuna	MPI Research Data Manager	EEZ	vessel name, location, catch effort, total catch weight, species caught, fishing method of tuna	>10	restricted
Marine Biosecurity Surveillance	MPI- Biosecurity	11 ports	fauna, flora	>10	restricted
Marlborough Shellfish Quality Programme	Marlborough Shellfish Quality	1 estuary	phytoplankton, shellfish tissue	Unknown	restricted
Nelson Pine Industries Limited Annual Monitoring	Nelson Pine Industries Limited	1 estuary	sediment (grainsize, ammoniacal-n), infauna and epibiota	>10	restricted
Rabbit Island Sludge Monitoring	Nelson Regional Sewerage Business Unit	1 estuary	sediment (nutrients {nitrogen, phosphorus}, grain-size, metals, organics), shellfish (metal content, faecal indicator bacteria), epifauna, infauna, macrophytes, microalgae	>10	restricted
Bell Island Benthic Surveys	Nelson Regional Sewerage Business Unit (NRSBU)	1 estuary	sediment (metals, ash-free dry weight, chlorophyll-a, grainsize, nutrients {nitrogen, phosphorus}), infauna, epifauna, macrophytes, heavy metals in shellfish tissue	>10	restricted
Bell Island Receiving Waters Survey	Nelson Regional Sewerage Business Unit (NRSBU)	1 estuary	water (ammoniacal-n-n, nitrate-n, nitrite-n, total nitrogen, dissolved inorganic nitrogen, dissolved reactive phosphate, total phosphorus, salinity, temperature, chlorophyll-a, turbidity), phytoplankton, faecal coliforms (seawater and shellfish), enterococci (seawater and shellfish)	>10	restricted
New Zealand King Salmon Rocky Reef Monitoring	New Zealand King Salmon Ltd	1 estuary	benthic invertebrates, algae, presence/absence, condition, abundance/diversity/area occupied by conspicuous biota	to10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Sea Temperature	NIWA	9 estuaries, 3 coastal	surface temperature	>10	public
Monitoring Coastal Processes	NIWA	13 coastal	cam-era monitoring of coastal processes such as detection of dunes, shoreline and sandbar position, rip currents, wave run-up, beach states	>10	restricted
NIWA Ocean Surface Colour	NIWA	EEZ	ocean colour from satellite	>10	restricted
Sea Surface Temperature Using Remote Sensing Satellite Technology	NIWA	EEZ	sea surface temperature (sst)	>10	restricted
Wave Monitoring	NIWA	8 coastal	Wave statistics	>10	restricted
Sea Level Database	NIWA	12 coastal	sea level	>10	public
NIWA Biophysical Moorings Database	NIWA	2 oceanic	water (particle flux, currents, temperature, light, nutrients, chlorophyll-a, microzooplankton, bacteria and phytoplankton concentrations at a variety of depths)	to 10	restricted
NIWA Coastal Moorings Database	NIWA	1 coastal, 1 estuary	water (temperature, salinity, currents, chlorophyll-a, oxygen, nitrate)	to10	restricted
Sea Level Database	Northland Regional Council	3 estuaries, 2 coastal	sea level	>10	public
SOE Sediment Programme	Northland Regional Council	2 estuaries	sediment (nitrogen, grainsize, lead, zinc, copper, total phosphorus, total organic carbon)	<5	public
SOE Water Quality Monitoring	Northland Regional Council	3 estuaries	water (salinity, oxygen, temperature, enterococci, faecal coliforms, dissolved reactive phosphate, total phosphorus, nitrate + nitrite,	>10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
			ammoniacal-n, turbidity, depth, total phosphorus, total organic carbon)		
Estuary Monitoring Programme	Northland Regional Council	5 estuaries	sediment (nickel, cadmium, phosphorus, nitrogen, redox, ash-free dry weight, grainsize, lead, zinc, chromium, copper), infauna, epifauna	to 10	public
Mangrove and Saltmarsh Habitat Mapping	Northland Regional Council	2 estuaries	estuarine vegetation and habitat mapping	>10	restricted
NZ Aluminium Smelters (NZAS) Wharf Seabed Monitoring	NZ Aluminium Smelters Ltd (Cawthron)	1 estuary	water clarity, sediment (grain-size, ash-free dry weight, metals {aluminium, arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, tbt}), sediment levels, video survey (sediment type, sediment accumulation, epifauna/epiflora)	<5	restricted
Otago Regional Council Estuary Monitoring Programme	Otago Regional Council	7 estuaries	sediment (nickel, cadmium, phosphorus, nitrogen, redox, ash-free dry weight, sediment grainsize, lead, zinc, chromium, copper), infauna, epifauna	to 10	public
Benthic Ecological Monitoring Of The Pan Pac Forest Products Ocean Outfall	Pan Pac Forest Products Ltd (Cawthron)	1 coastal	sediment (grainsize, ash-free dry weight, redox depth), photomicroscopy of the sediment cores to identify the presence/absence of pulp mill fibre, infauna	>10	restricted
Whangateau Cockles	Pilditch, UoW?	1 estuary	cockle abundance and size	>10	restricted
Shakespeare Bay Stormwater Consent Benthic Monitoring	Port Marlborough New Zealand Ltd	1 estuary	sediment (grainsize, ash-free dry weight, total organic carbon, nitrate, total nitrogen, metals, total hydrocarbons, organotin compounds), *Mytilus galloprovincialis* tissue (metals, svocs, pahs), infauna	to10	restricted
Shakespeare Bay Stormwater Consent Benthic Monitoring	Port Marlborough New Zealand Ltd	4 control stations	sediment (grainsize, ash-free dry weight, total organic carbon, nitrate, total nitrogen, metals, total hydrocarbons, organotin compounds), infauna, *Mytilus galloprovincialis* tissue (metals, svocs, pahs)	to10	restricted

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Tasman Bay Dredge Spoil Disposal: Environmental Monitoring	Port Nelson Ltd	1 control zone	sediment (metals {copper. lead, zinc}, grainsize), infauna, *Austrofusus glans* tissue contamination (organochlorine pesticides, pcbs, mercury), shellfish imposex assays	to10	restricted
Port Nelson/ Nelson City Council Long Term Programme	Port Nelson Ltd, Nelson City Council	1 port, 1 estuary	sediment (metals, grainsize, organic matter, svocs, organotins, tins), infauna, epifauna	<5	restricted
Schiel	Schiel, UoC	6 coastal	intertidal reef benthic communities	>10	restricted
Sealord Fisheries Outfall	Sealord	1 estuary	sediment (grainsize, ash-free dry weight, total kjeldahl nitrogen, mercury), infauna, algae, epifauna	>10	restricted
Leigh And Mokohinau Islands	Shears, UoA	2 coastal	sedimentation rates, reef benthic communities	>10	restricted
Island Bay Ctd	Shima, Victoria U	1 estuary	water (conductivity, temperature, depth)	<5	public
Kau Bay Ctd	Shima, Victoria U	1 estuary	water (conductivity, temperature, depth)	<5	public
Sea Level Database	Taranaki Port Company	1 port	sea level	>10	public
Port Taranaki Sediment Quality	Taranaki Regional Council	1 port	sediment (cadmium, lead, zinc, copper, arsenic)	<5	public
Bathing Beach Water Quality	Taranaki Regional Council	9 coastal	water (salinity, conductivity, temperature, pH, *E. coli*, enterococci, faecal coliforms)	>10	public
Hard Shore Marine Ecological Monitoring	Taranaki	6 coastal	epifauna	to10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
Programme	Regional Council				
Soft Shore Monitoring	Taranaki Regional Council	2 coastal	infauna, epifauna	to10	public
Sea Level Database	Tasman District Council	1 port, 1 coastal	sea level	>10	public
Tasman District Estuary Monitoring Programme	Tasman District Council	5 estuaries	sediment (nickel, cadmium, phosphorus, nitrogen, redox, ash-free dry weight, grainsize, lead, zinc, chromium, copper)	>10	public
Tasman Estuary Monitoring Programme	Tasman District Council	5 estuaries	infauna, epifauna	>10	public
Waimea Inlet SOE	Tasman District Council	1 estuary	sediment (metals, total nitrogen, total phosphorus, ash-free dry weight, grain-size, chlorophyll-a, redox), epifauna/infauna, macroalgae	>10	restricted
Tasman Bay SOE	Tasman District Council	1 coastal	water (conductivity, temperature, chlorophyll-a, turbidity), sediment (grainsize, nutrients {nitrogen & phosphorus}), wind velocity/direction, air temperature, barometric pressure, current velocity/direction, epifauna, infauna	to10	restricted
Sea Level Database	Timaru Port Company	1 port	sea level	>10	public
Sea Temperature	UoA	1 coastal	surface temperature	>10	public
Sea Temperature	UoO	1 estuary	surface temperature	>10	public
Marlborough Sounds Mussel Farms Data	Various mussel farm companies	1 estuary	benthic invertebrates, algae, various sediment parameters	>10	restricted
Sea Level Database	Waikato Regional	2 estuaries	sea level	>10	public

Name of Database	Owner	Location type	Variables measured	Length of monitoring (years)	Access constraints
	Council				
Coastal Water Quality For Contact Recreation - Discontinued.	Waikato Regional Council	24 coastal	water (salinity, temperature, enterococci)	>10	public
Regional Estuary Monitoring Programme (REMP)	Waikato Regional Council	2 estuaries	sediment (chlorophyll-a, grainsize), infauna	>10	public
Estuary Vegetation Mapping	Waikato Regional Council	14 estuaries	estuarine vegetation and habitat mapping	to10	public
Pollutants In Sediments	Waikato Regional Council	2 estuaries	sediment (nickel, cadmium, sediment grainsize, lead, zinc, chromium, copper, arsenic, organics, antimony, mercury and silver)	to10	public
Estuarine Water Quality Monitoring Programme.	Waikato Regional Council	6 estuaries	water (salinity, oxygen, temperature, pH, enterococci, faecal coliforms, total phosphorus, nitrate + nitrite, ammoniacal-n, turbidity)	>10	restricted

The majority of the databases come from regional councils and unitary authorities (Figure 1a).

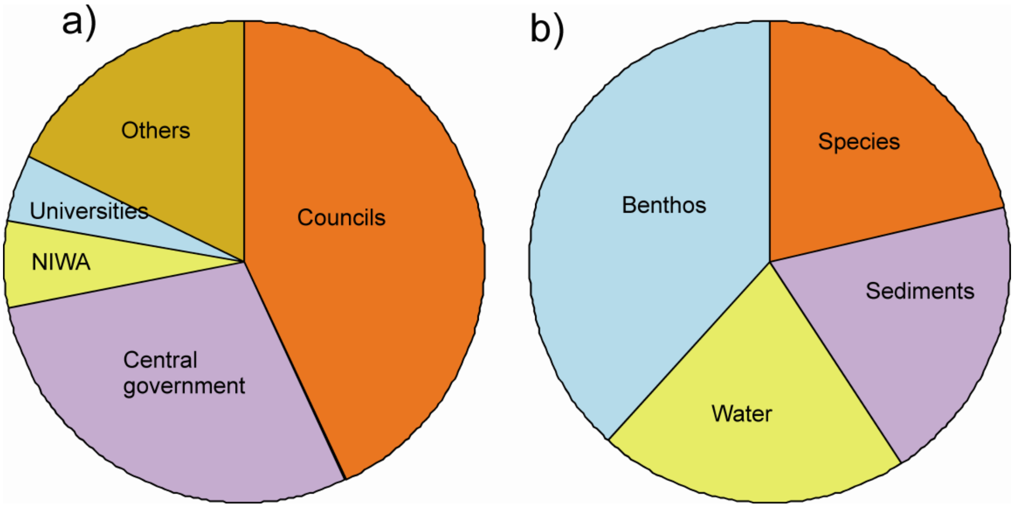

Figure 1: Proportion of databases (a) supplied by different organisations (Councils include unitary authorities, Others include NGOs and Industries), (b) recording measurements on characteristics of the water column, the sediments, benthos (animals or plants) or focusing on selected species.

Information on species living on the seafloor (benthos) was held in the majority of databases (Figure 1b) and nearly half of those databases also hold information on sediment characteristics. Most of the databases have been in operation for more than 10 years (60%) and around 10% have only been in operation for less than five years. All of the Regional Council datasets have been analysed for changes and some changes have been observed and incorporated into management activities.

More information about the monitoring of specific variables will be given in Section 4.

4 FACTORS TO CONSIDER FOR MONITORING AT A NATIONAL LEVEL

4.1 Introduction

Recent activities of central and local government and scientists (See Section 2.2) has focused on the need to report[3] on:

- physical and chemical trends in the environment especially those related to climate change, increased sediment loading and turbidity, discharge of contaminants, nutrient levels, ocean acidification; dumping of dredged sediment, mining and aquaculture (see MacDiarmid et al. 2012a);
- biogeographic and oceanographic character, particularly at water mass and latitudinal or longitudinal boundaries;
- ecological status, health, integrity and resilience and ecosystem goods and services;
- the presence or occurrence of non-indigenous species;
- the number of species in the threatened, at risk and protected species categories;
- productivity that may affect fisheries and aquaculture outputs (e.g., water column and benthic primary and secondary productivity).

There are many variables that could be measured to enable reporting on the factors listed above, however, not all variables are equally fit for national reporting. Variables suitable for national reporting must be informative for policy needs, represent or be a surrogate for one or more factor that policy or managers require information on, have standard methods of measurement, and be recorded with sufficient accuracy to detect relevant changes. Preferably, their responses to specific pressures must be known (so that causes of change can be determined), and natural variability must be able to be removed in analysis from trends related to anthropogenic activities. Finally, for the purposes of this report, MPI requested that they should also either be monitored internationally (either in other nations' programmes or in large international programmes) or presently be extensively monitored in New Zealand.

To reduce the list of variables that needed to be initially considered, but at the same to ensure that all likely variables were included, workshops and questionnaires were used to build a large list of potential variables and then select a subset for detailed investigation (see Appendix 6 for methodology, and the complete list). To ensure that policy needs were being captured effectively, a review of legislative requirements was made (Froude 2013), and structured phone conservations to gain more details about reporting requirements (Appendix 7) were held with policy representatives from MPI, MfE, DOC, LINZ, EPA, Ministry of Economic Development -Tourism, Ministry of Foreign Affairs, Maritime New Zealand, Statistics New Zealand and regional councils.

Thirty-five environmental variables were selected for detailed investigation, including eleven biological variables (Appendix 6, Table 3), all but one of which could be considered to be states in the Pressure-State-Response (PSR) framework suggested for use by MfE. It is important to recognise that many biological variables respond both indirectly to pressures (i.e., they respond to the change in one or more 'state' variables) and directly (e.g., they are removed/damaged by fishing, dredging, dumping, increased population pressure amongst others). Twelve variables to be measured in sediments of the seafloor (a mix of pressures and states) were selected for detailed investigation as were twelve to be measured in the water (again generally a mix of pressures and states).

Localised monitoring programmes are generally not designed for national scale reporting but often collect information about variables that are relevant at a national scale. This section reports in detail on the prioritised list of variables (see biological variables (Section 4.1, Table 3), sediment variables

[3] Note that this list does not include marine recreational water quality variables, which is monitored by Regional Councils, under guidance from the NZ Recreational Water Quality Guidelines (MfE/MoH 2003). Reporting these results at a national level is effected by MfE (e.g., see http://www.mfe.govt.nz/environmental-reporting/freshwater/recreational/local.html).

(Section 4.2, Table 4) and water variables (Section 4.3, Table 5)). For each variable the following information that was used to judge its fitness for SOE reporting at a national level is given:

i. **Use** - What the variable represents, or is a surrogate for, and what it could contribute to reporting.
ii. **Responsiveness** - What stressors will affect the variable and whether the degree of response is known. Note that this section will not be applicable for most variables that are themselves stressors.
iii. **Variability** - Whether the variable has low natural variability or whether trends related to anthropogenic activities are likely to be able to be distinguished from natural temporal variability.
iv. **Degree of monitoring** - Whether monitoring the variable would aid in consistency with international data, and to what degree the variable is presently monitored in New Zealand. This includes information on sampling coverage and frequency.
v. **Methods** - Methods used within New Zealand and any problems.
vi. **Utility in MEMP**- A summary of the above factors translated into scores as follows:
    - Use:
        - contributes to single indicator (1), or multiple indicators (2);
        - can be used to assess ecosystem health (1);
        - is a surrogate for other ecosystem components (1);
        - is specifically mentioned in regulations (1);
        - is a known driver of another component (1) or many components (2).
    - Responsiveness: known to respond to single (1) or multiple (2) stressors;
    - Natural temporal variability:
        - is known and does not prevent detection of change (1);
        - is unknown or high and may prevent detection of trends (-1);
    - Degree of monitoring:
        - frequently monitored overseas (1);
        - can be assessed from satellite data over the EEZ and Territorial Sea (5);
        - can be assessed from satellite data over the EEZ or Territorial Sea (4),
        - is monitored in some locations to the north, south, east and west of New Zealand (3);
        - is monitored in some locations in 3 of the 4 quadrats (2);
        - is monitored in more than one location (1);
        - is unmonitored in New Zealand (0).
    - Methods;
        - there is a single standard method (2), multiple standard methods (1);
        - no standard method (-1);
        - hard to measure accurately (-1);
        - no standard definitions (-1).

A summary of which of these variables could presently most readily form part of a monitoring programme at a national level is given in Section 5. Section 6 discusses what extra monitoring or research would be needed to robustly report on changes over time in the status of the marine environment.

4.2 Biological variables

Soft-sediment macroinvertebrate communities: invertebrates living on the surface and within the sediment sized 0.5 mm to 100 mm, generally identified and counted to genera or species level. This is a composite variable i.e., the data can be analysed as community composition, as one of a number of biodiversity measures (e.g., species richness, species evenness) or even as individual species.

Use. Macroinvertebrate communities of soft sediments (intertidal and subtidal) are widely used internationally and nationally for monitoring as a surrogate for ecosystem health (Alden et al. 2002, Borja et al. 2008, Villnäs & Norkko 2011) as they integrate responses to environmental conditions over time periods of days to months, are a food source for some fish, birds, and humans, are relatively stationary and are sensitive to climate change factors and most anthropogenic activities. They (either at the community, species or biological trait level) provide many ecosystem goods and services, from food production and recreational opportunities to contaminant processing and cultural benefits. Many of the organisms that comprise these communities have been demonstrated to increase nutrient and sediment fluxes between the sediment and the water column (Lohrer et al. 2010, Lohrer et al. 2011, Needham et al. 2011, Thrush et al. 2006) and thus to drive primary productivity and ecosystem functioning in shallow water systems. Macroinvertebrate community data can be used to calculate biodiversity indices, and both the community data and individual species abundances contribute to the calculation of ecological integrity and ecosystem goods and services.

Responsiveness. New Zealand studies have investigated responses[4] of benthic macrofauna to terrestrial sediment inputs (Lohrer et al. 2003, Norkko et al. 2002, Thrush et al. 2003), dumping and dredging (Paavo 2007, Roberts et al. 1998), fishing (Cryer et al. 2002, Cryer et al. 1987, Thrush et al. 1995, Thrush et al. 1998), eutrophication (Rogers 1999, Savage 2009), contamination (Hewitt et al. 2009, Thrush et al. 2008) and climate change factors (e.g., sea level rise, acidification, temperature and wave exposure (Cummings et al. 2013, Paavo et al. 2011)). Internationally, they have also proven to be susceptible to alterations in freshwater inflows and mining.

Variability. Within New Zealand's intertidal areas, understanding of natural spatial and temporal variability is progressing (Hewitt & Thrush 2007, Hewitt & Thrush 2009, Hewitt & Thrush 2010), allowing natural variability to be separated from anthropogenic changes (e.g., Hewitt & Thrush 2010). Recent New Zealand research has highlighted potential methods for determining benthic community health and functioning (Hewitt et al. 2009, Rodil et al. 2013).

Degree of monitoring. Soft-sediment macrofauna are used in many national-level monitoring programmes elsewhere and form the basis of a number of environmental health indices (e.g., ITI, California (Word 1978); Multivariate-Ambi, European coasts (Muxika et al. 2005); BOPA, English Channel (Dauvin et al. 2007) and references in table 2.3 of Hewitt et al. (2014)). In New Zealand, soft-sediment macroinvertebrate community data are collected from intertidal areas of estuaries by most regional councils and unitary authorities (Figure 2) with a view to State of the Environment reporting on biodiversity and benthic community structure. New Zealand specific indices (BHM, Hewitt et al. 2005; TBI Rodil et al. 2013) have been developed for Auckland estuaries and are being tested in other areas. Frequency of sampling varies from bimonthly to five yearly.

Methods. Reasonably consistent methodologies are used across the country, i.e., the mesh size used is 0.5 mm and core size used is either 13 or 12.5 cm diameter × 15 cm deep. Taxonomic resolution of the macroinvertebrate identifications is presently variable, although steps are underway to correct this.

Utility in MEMP. This composite variable performs well on all five counts (see Table 3): it can be made use of directly or indirectly in reporting biodiversity, health, ecosystem goods and services and ecological integrity; enough is known about responses to individual stressors to enable causes of changes to be assessed; in estuaries the natural variability should not preclude detection of changes; this data is used in many countries in their monitoring programmes; and the methods are consistently and extensively applied across New Zealand.

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[4] Manipulative experiments are only one way of determining cause and effect (see Peters 1991, Hewitt et al. 2007), which have a number of problems if they are used to elucidate effects at large scales (e.g., Thrush et al. 2009). However, in the vast majority of cases in this report, the responses to stressors have been determined robustly by a mix of both manipulative experiments and correlative surveys.

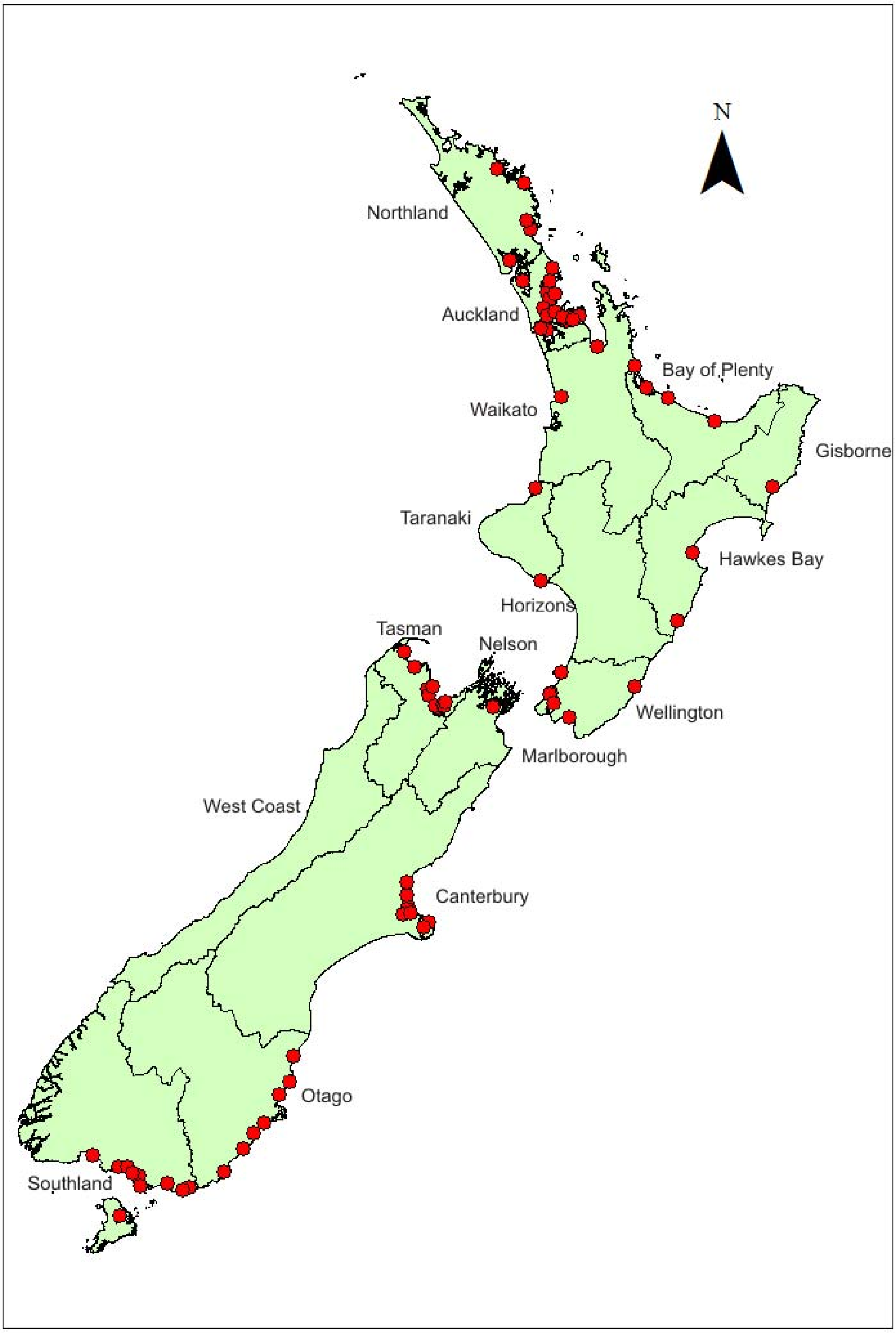

Figure 2: Location of current intertidal soft-sediment macroinvertebrate monitoring sites listed in the MEMP meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Table 3: Summary of utility of biological variables for a national MEMP. Scoring is defined at end of Section 4.1.

		scores as	*maximum possible score*	Soft-sediment macroinvertebrate communities:	Biogenic habitats	Reef macroalgae and macrofaunal communities	The number of species in the threatened, at risk, or protected categories	Non-indigenous species	Soft sediment epibiotic communities	Key species	Reef fauna	Demersal fish communities	Zooplankton and phytoplankton
Use	Contributes to indicators	*1 or 2*	*2*	2	2	2	2	1	2	2	2	2	2
	Can assess health	*1*	*1*	1	1				1				
	Surrogate for other ecosystem components	*1*	*1*	1	1				1				1
	Specifically mentioned in policy	*1*	*1*				1	1					
	Driver of other components	*1 or 2*	*2*										
Responsiveness	Single or multiple pressures	*1 or 2*	*2*	2	2	2			2		1	1	1
Natural temporal variablity	Does not prevent detection of trends	*1*	*1*	1		1			1		1		
	Unknown	*-1*	*-1*		-1		-1	-1		-1			
	High	*-1*	*-1*										-1
Degree of monitoring	Overseas	*1*	*1*	1	1	1	1	1	1	1	1	1	1
	Spatial coverage of present NZ monitoring	*1–5*	*5*	3	1	1	1	3	1		1	3	1
Methods	Standard method 1 (more than one standard method), 2 (only one standard method)	*1 or 2*	*2*	2				2				1	1
	Hard to measure accurately	*-1*											
	No standard methods	*-1*	*-1*		-1	-1	-1		-1	-1	-1		
	No standard definitions	*-1*	*-1*		-1					-1			
	Total		*13*	13	5	6	3	7	8	-2	5	8	6

Biogenic habitats: Habitats created by the plants and animals living in them. This is usually a composite variable (e.g., % cover, density, size) of either a single habitat or multiple habitats. In the case of multiple habitats, a number of measures of habitat diversity are usually calculated (e.g., habitat richness, diversity, connectedness, fragmentation).

Use. Type and extent of biogenic habitats affect the biodiversity of animals and plants living within them (Harborne et al. 2008, Pratchett et al. 2011), productivity (Tait & Schiel 2011) and nutrient/sediment/oxygen fluxes (Eyre et al. 2011), and are increasingly being used in the assessment of ecosystem goods and services (Townsend et al. 2011). Their diversity within an area has been used as a surrogate for biodiversity of other components (Thrush et al. 2001), and their type and extent is used in the calculation of ecosystem integrity (Thrush et al. 2012). Some regional councils have begun trialling the application of the Marine Habitat Assessment Decision Support (MarHADS; MacDiarmid et al. 2012b) to assess the state of coastal marine environments taking into account habitat vulnerability, quality and quantity. Changes in certain habitat types are of interest in themselves, e.g., the extent of mangroves, saltmarsh, seagrass and shellfish beds especially are of interest to local communities. Changes in extent of essential fish habitats, which are frequently biogenic at fine scales, are of interest to fishers.

Responsiveness. Many biogenic habitats are sensitive to anthropogenic stressors (e.g., terrestrial sediment inputs, dumping, dredging, mining, fishing, physical disturbance, temperature, freshwater inputs, eutrophication, contamination, changes in productivity and climate change (e.g., sea level rise, acidification)). Generally though, specific habitats will be sensitive to a specific set of stressors. Thus, relative changes to specific biogenic habitats can be used to assess overall status (i.e., from heavily stressed to healthy).

Variability. Little is known about the natural variability of most habitats, with the exception of recent analyses on mangrove cover (A. Swales NIWA pers. comm.) or the time scale at which responses to stressors are likely to occur.

Degree of monitoring. Many nations' monitoring of biogenic habitats has focused on habitats deemed to be of particular importance. These habitats have generally been determined at a national level by workshops. In New Zealand no such list exists, in fact there is not even a nationally consistent definition of what constitutes a biogenic habitat, although work on this has begun (Department of Conservation & Ministry of Fisheries 2011). The spatial distribution of coastal vegetated habitats has been determined around much of the country. At this stage the records represent a baseline for a particular point in time, and provide the start of time series information should they be repeated in future. Monitoring of other biogenic habitats (e.g., sponge gardens, cockle beds, tube worm mats) is less consistently done, with the following exceptions. (1) Waikato Regional Council has recently mapped intertidal biogenic habitats in the East Coast estuaries with the aim of repeating sampling (Needham et al. 2013). (2) Auckland Council has a coastal programme for mapping sedentary and biogenic habitats in nearshore areas, by aerial photography and video, which is intended to have a 15 year repeat cycle. (3) Some regional councils and unitary authorities, using the MfE Estuarine sampling protocol, do rotational mapping of a few biogenic habitat types as proposed by Robertson et al. (2002). (4) Some habitat mapping within the Leigh Marine Reserve and the Mimiwhangata Marine Park has been conducted using techniques described in Grace & Kerr (2005).

Methods. Coastal vegetated habitats are generally surveyed using aerial photography, with satellite imagery being trialled in Auckland (J. Walker AC pers. comm.) for rocky reef shallow water habitats. There are no nationally consistent, cost-effective methods for surveying other biogenic habitat types.

Utility in MEMP. This variable performs well on three counts (see Table 3): it can be made use of directly or indirectly in reporting biodiversity, health, ecosystem goods and services and ecological integrity and its diversity can be used as a surrogate for biodiversity of other components; enough is known about responses to individual stressors to enable causes of changes to be assessed; and these types of habitats are frequently monitored overseas. However, little is known about how naturally variable they are over time; there is no nationally consistent definition of what constitutes a biogenic habitat or consistent cost-effective methods; and little present monitoring is done in New Zealand. It is presently not suitable for being included in an MEMP.

Reef macroalgae and macrofaunal communities: all seaweeds and invertebrates living on the surface of rocky areas, sized over 0.5 mm, generally identified to genera or species level with either counts made or percent cover estimated. This is a composite variable i.e., the data can be analysed as community composition, as one of a number of biodiversity measures (e.g., species richness, species evenness) or even as individual species or biomass.

Use. Both intertidally and subtidally, these types of communities affect ecosystem goods and services, fish biomass and nutrient and oxygen fluxes between the sediment and the water column. The community data can be used to calculate biodiversity indices and contribute to the calculation of ecological integrity and ecosystem goods and services. However, there are yet no methodologies for relating community structure to community health.

Responsiveness. Reef communities have been demonstrated to be affected by trampling, anchoring, sedimentation and temperature (Schiel et al. 2004, Schiel & Taylor 1999, Schiel et al. 2006, Walker 2007). They are also likely to be affected by eutrophication and climate change (e.g., sea level rise, changes in weather patterns, seawater temperatures and acidification), although such impacts are only recently being studied in New Zealand (Cummings et al. 2013).

Variability. For a few intertidal areas, natural temporal variability is beginning to be understood (Cape Campbell, Kaikoura and Moeraki, Schiel 2011), suggesting that separation of natural variability from anthropogenic change will be possible. In subtidal areas, Wing & Jack (2010) document temporal changes in the Fiordland rocky reef sessile epibenthos and reef fish community structure over time (1985 – 2010). Changes in the abundance of lobster, linked to the presence of ten marine reserves, were able to be detected above the natural spatial and temporal variability (Jack & Wing 2013).

Degree of monitoring. Many countries monitor reef communities, especially where hard substrate reefs form a large or socially important part of the marine system (e.g., Great Barrier Reef). In New Zealand, reef macroalgal and macrofaunal communities (Figure 3, Figure 4) are mostly monitored intertidally. Some subtidal monitoring is conducted in the Auckland Region and in marine reserves in Fiordland and Stewart Island; the latter programme has recently been extended to the Snares and Auckland Islands (Wing 2007, Wing & Jack 2010, Wing pers. comm.). However, while long-term monitoring sites are restricted in number, there is a considerable database of once- or twice-only surveys around New Zealand, both intertidal (at least 100 sites, Schiel pers. comm.) and subtidal (e.g., Schiel & Hickford 2001 and pre- and post-reserve monitoring). Such data are not only useful for understanding broad biogeographic patterns but could be used as a baseline for future monitoring.

Methods. Intertidal reef macroalgal and macroinvertebrate communities monitoring uses varying methodologies, particularly with respect to quadrat size. Monitoring also varies in frequency from quarterly to irregular. A consistent method of monitoring and classifying subtidal reef communities at a fixed depth and slope was developed by Shears (2007), but sampling to determine natural temporal variability over time in this classification has not yet been undertaken.

Utility in MEMP. This composite variable performs well on one count (see Table 3): it can be made use of directly or indirectly in reporting biodiversity, health, ecosystem goods and services and ecological integrity, even though there are yet no methods for assessing health from the community data. It performed less well in terms of known responses to stressors. Moreover, little is yet known about natural variability; it is not always part of national monitoring programmes and there is little national coverage within New Zealand. More importantly there are yet no standard methods accepted across the country. It is presently not suitable for being included in an MEMP.

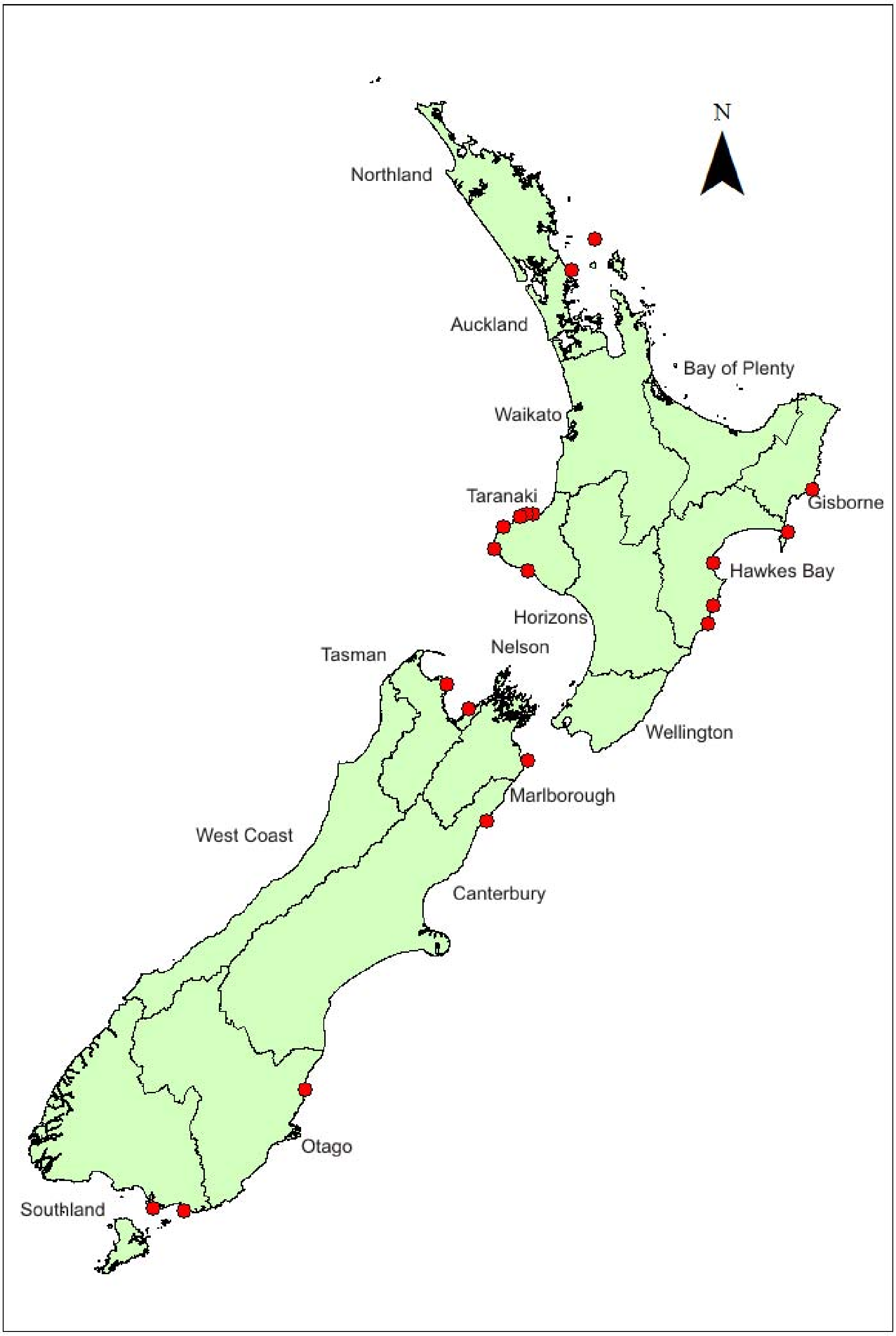

Figure 3: Location of current intertidal reef community monitoring sites listed in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

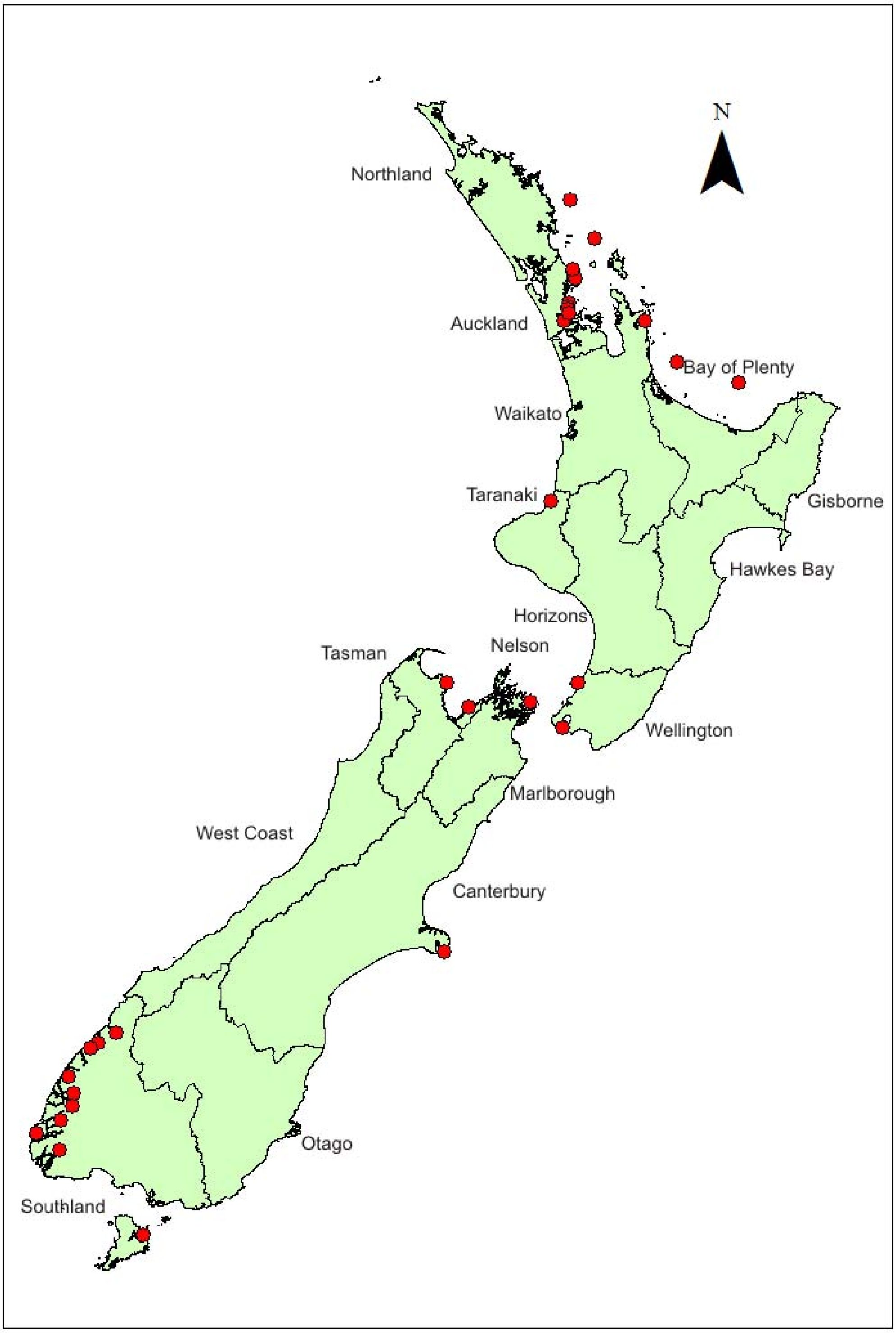

Figure 4: Location of current subtidal reef community monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

The number of species in threatened, at risk, or protected categories: In New Zealand, protected species include all marine mammals, all seabirds (except black-backed gull *Larus dominicanus*), all marine reptiles, nine species of fish (deepwater nurse shark *Odontaspis ferox*, white pointer shark *Carcharodon carcharias*, whale shark *Rhincodon typus*, basking shark *Cetorhinus maximus*, oceanic white-tip shark *Carcharhinus longimanus*, manta ray *Manta birostris*, spinetail devilray *Mobula japanica*, giant grouper *Epinephelus lanceolatus* and spotted black grouper *Epinephelus daemelii)* and all species of corals in the Orders Antipatharia (black corals), Gorgonacea (now Alcyonacea) (gorgonians), Scleractinia (stony corals) and the Family Stylasteridae in Order Anthoathecata (hydrocaroals). The Wildlife Act 1953 and its associated Schedules are the definitive source of information on species afforded protected status. For example, Schedule 7A lists details of corals and fish protected by the Act. Additionally, the Department of Conservation operates the New Zealand Threat Classification System which has as a long-term goal to list all extant species in New Zealand according to their threat of extinction and there is increasing coverage by the process. The system is made up of manuals and corresponding taxa status lists, currently extending to 23 groups of taxa. This classification can differ slightly from the International Union for Conservation of Nature (IUCN) classification depending on the size of the New Zealand population relative to the global population.

Use. Protected species fall under the provisions of the Fisheries Act 1996, the Marine Mammals Protection Act 1978 and the Wildlife Act 1953. The number of species in the threatened, at risk, or protected categories are reported for the country as a whole. Information on their occurrence within particular areas is expected to contribute to measures of ecosystem integrity (Thrush et al. 2012) and to spiritual and cultural aspects of ecosystem goods and services. There is no information as to the change in number of species in various levels of protection being a useful surrogate for change in other ecosystem components.

Responsiveness. There are no known strong relationships between protected species status and specific stressors. However, a project that investigates the spatial distributions of a suite of protected species (seabirds, marine mammals and white sharks) in order to construct habitat-use models in relation to anthropogenic threats is currently underway (NIWA TMMA143). There are also some known relationships between at risk status of specific species and specific stressors. However, the overall number of species in the various categories is more representative of a nation's commitment to management and understanding of at risk species than to the number and magnitude of stressors.

Variation. Temporal variation in the number of species in threatened, at risk or protected categories is low as species are rarely removed from these categories.

Degree of monitoring. Most nations collect data on the number of species in threatened, at risk or protected categories, although the identity of the species often varies between countries. Within New Zealand, targeted programmes estimate annual seabird strikes and mammal deaths caused by fishing. Modelling approaches are used to assess the status of selected marine mammal populations and DOC's Threat Classification System makes assessments over a three year cycle.

Methods. MPI (particularly through the Aquatic Environment Working Group) and DOC (particularly through DOC's Conservation Services Programme) develop annual and longer-term plans that identify research needs for protected species that are affected by commercial fishing operations. For example, MPI and CSP have recently carried out a level 2 risk assessment for all New Zealand seabirds in relation to fishing that will be used, in part, to identify data gaps that will be addressed in order to refine future iterations of the assessment and reduce species' risk status. Similar work is underway for marine mammals.

Utility in MEMP. This variable performs reasonably well with respect to use; it can be made use of directly or indirectly in reporting ecosystem goods and services and ecological integrity (Table 3). It is also frequently included in national monitoring programs overseas and strategic monitoring is occurring in New Zealand. However, the overall number of species in the various categories is more representative of a nation's commitment to management and understanding of at risk species than to the number and magnitude of stressors.

Non-indigenous species: Species that are not native to New Zealand, sometimes also called invasive or non-native species, this term also includes those species considered pests. However, not all non-indigenous species necessarily become pests or invasive, thus those terms are no longer used. This is a composite variable, the data can either be analysed as total number of non-indigenous species or as individual species.

Use: Non-indigenous species can have a range of effects on marine ecosystems, the severity of which are often species and context dependent. The number (or changes over time in the number) of such species is not therefore a particularly useful indicator of marine health, although it is suggested that the number of such species should be included in New Zealand definitions of ecological integrity. On a geographic scale, three factors will have a bearing on the overall impact of a non-indigenous species: the total area it occupies, its abundance, and some measure of the functional impact of individuals (Parker et al. 1999). The Marine High Risk Site Surveillance programme (MPI) and Marine Invasives Taxonomic Service (NIWA) maintain/contribute temporal data relevant to two of these factors: national range distribution and relative abundance (measured as prevalence). To date little is known about the functional impact, although if this information was known the contributions of non-indigenous species to ecosystem goods and services could be assessed.

Responsiveness and Variability. Information on temporal variability and responses of non-indigenous species to specific stressors would need to be gathered on an individual species basis and as yet there is little information available.

Degree of monitoring. Non-indigenous species are monitored by many nations. In New Zealand's marine environment this is achieved by the national Marine High Risk Site Surveillance programme, which collects data every six months in 11 harbours that have ports and marinas of first entry for international vessels (Figure 5). Its primary objective is to detect incursions by five high risk marine organisms listed on the New Zealand Unwanted Organisms Register that are not yet present in New Zealand. Secondary objectives include detection of new incursions by other non-indigenous species and range extensions by established non-indigenous species. Several councils have implemented their own limited marine pest surveillance, in association with their coastal monitoring programmes and are able to submit specimens to Marine Invasives Taxonomic Service for identification once they have reported them through MPIs pest and disease hotline (0800 80 99 66). Councils are gradually building their expertise in this area and in future could be another source of reasonably robust information about the occurrence of non-indigenous species.

Methods. Monitoring is mainly conducted by a single programme using a standard methodology.

Utility in MEMP. This variable performs well on three counts (see Table 3): it can be made use of directly or indirectly in reporting ecosystem services and ecological integrity, in conjunction with information on the native species in the surrounding communities and it is a stressor; the variable is used in many countries' monitoring programmes; and the methods are consistently and widely applied across New Zealand. However, little is known about individual species natural temporal variability or their responses to individual stressors.

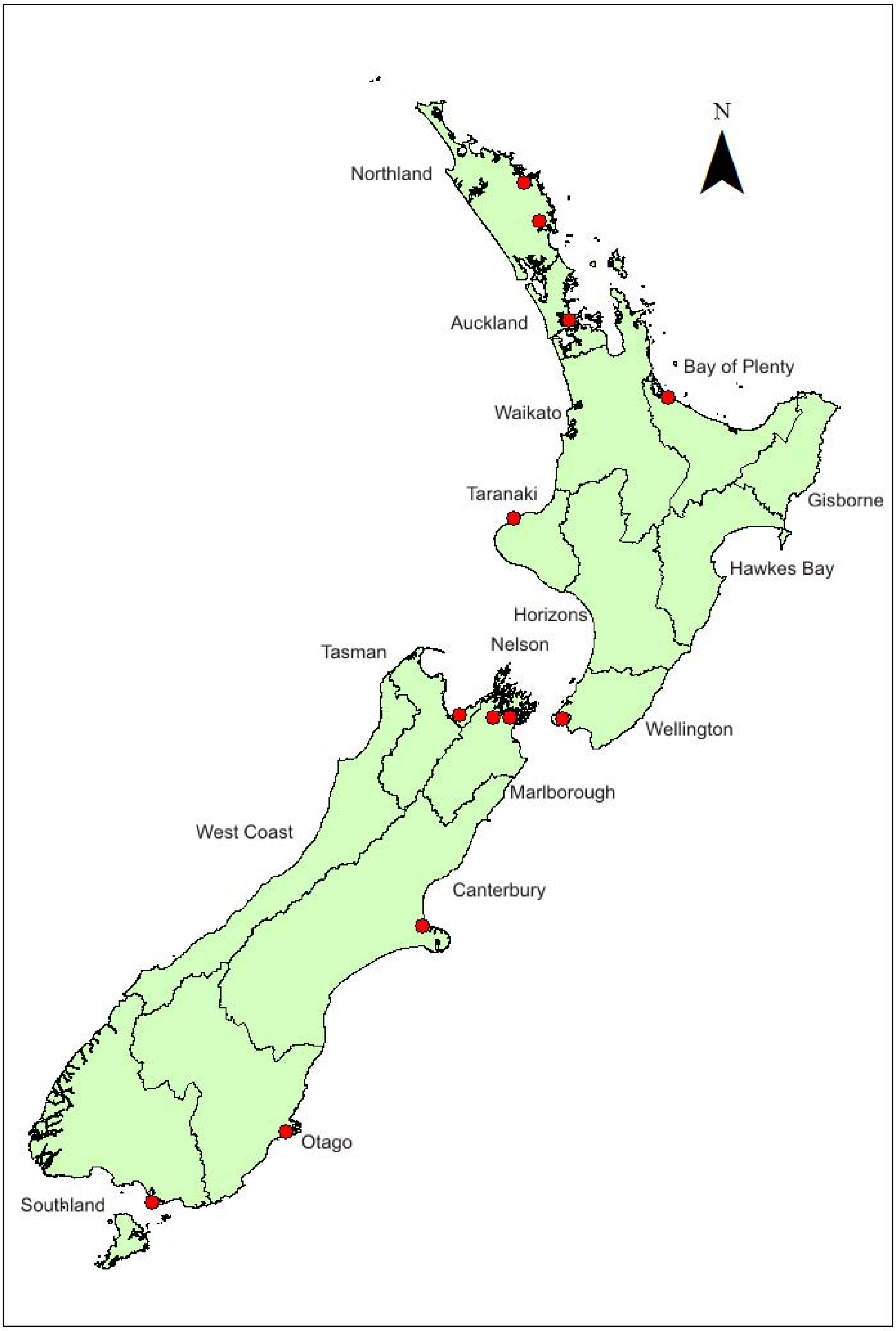

Figure 5: Ports presently monitored by the national Marine High Risk Site Surveillance programme.

Soft sediment epibiotic communities: Invertebrates and fauna living on or protruding from the surface of the seafloor, generally sized greater than 50 mm. This is a composite variable i.e., the data can be analysed as community composition, as one of a number of biodiversity measures (e.g., species richness, species evenness) or even as individual species.

Use. Subtidally, these communities have been suggested for use as surrogates for biodiversity of fish, smaller animals and microphytes (Thrush et al. 2001, 2002) and are a key link in many ecosystems to higher trophic levels (Pinkerton 2013). Similar to soft-sediment macroinvertebrate communities, they are widely used internationally for assessment of ecological condition as they integrate responses to natural conditions and anthropogenic pressures over time (from days to years), are a food source, are relatively stationary and are sensitive to most anthropogenic activities. They provide many ecosystem goods and services (from food production and recreational diving opportunities to contaminant processing and cultural benefits). The community data can be used to calculate biodiversity indices and contribute to the calculation of ecological integrity and ecosystem goods and services.

Responsiveness. There are a number of New Zealand studies that define the relative sensitivities of different soft-sediment epibiotic communities to terrestrial sediment inputs (Lohrer et al. 2003, Norkko et al. 2002, Thrush et al. 2003), dumping and dredging (Paavo 2007), fishing (Cryer et al. 2002, Cryer et al. 1987, Thrush et al. 1995, Thrush et al. 1998) and climate change factors such as acidification and temperature (Tracey et al. 2013). Internationally, they have proven to be susceptible to eutrophication, alterations in freshwater inflows and mining.

Variability. There is little information available about natural temporal dynamics, but the relatively sedentary nature of most of the organisms suggest that it is probable that anthropogenic-related changes could be disentangled from natural temporal dynamics.

Degree of monitoring. National-level monitoring programmes in countries using this variable usually focus on small areas in specific places. In New Zealand, there is little ongoing monitoring of soft sediment epibiotic communities and most of the existing data has been collected by one-off surveys, e.g., Oceans Survey 2020, initial surveys of marine reserves (Figure 6). The Auckland Council coastal programme for mapping sedentary and biogenic habitats in nearshore areas, which is intended to have a 15 year repeat cycle, also collects epibiotic community data.

Methods. No standard methods exist, with methods varying from short diver transects or quadrats to towed video over longer extents to towed gear taking photographic images. For all methods, resolution is strongly dependent on visibility and tow speed. However, there is research being undertaken to understand the effect of resolution on measurements (NIWA Coasts and Oceans core funding, Programme 5).

Utility in MEMP. This composite variable performs well on all counts (see Table 3), except for methods and the degree of monitoring presently being done within New Zealand. It is presently not suitable for being included in an MEMP.

Key species: Key species are those which play an important role in ecosystem functioning or that people particularly value.

Use. Key species are important in assessing ecosystem goods and services and may also be important in calculating ecological integrity and functioning.

Responsiveness, Variability and Methods. Without guidance on which species are considered to be "key" in New Zealand (see degree of monitoring section below), it is not possible to discuss their sensitivities to stressors, their natural temporal variability, nor whether there are methodological problems.

Degree of monitoring. Most countries' monitoring programmes have some key species monitoring, just as they have some biogenic habitat monitoring, although the species they consider to be key vary between countries. Key species to monitor are generally chosen as a compromise between scientific assessment of their importance to the rest of the ecosystem, social values and sampling practicalities. An essential component to monitoring of key species is a consensus on which species are key and construction of a national list of key species, which New Zealand does not presently have. At present, monitoring (excluding fisheries stock assessments) of some specific species is conducted, although there is no claim that they are key species. Abundance and sizes of selected shellfish species are conducted intertidally at a number of beaches generally at irregular intervals (MPI *beaches* database). The same database also holds information on sea lettuce densities (as dry weight). Information on *Eklonia* (density only), rock lobster abundance and size (Figure 7), blue cod abundance and size (Figure 8), paua abundance and kina abundance are collected irregularly in a number of marine reserves (e.g., for Fiordland sites see Jack & Wing 2013).

Utility in MEMP. At present New Zealand does not have any consensus of what species are considered to be "key". Natural spatial variations in a key species distribution would result in different species having to be monitored in different places, complicating national analysis and reporting on change. This is due to two factors: (1) different species may have different sensitivities to stressors; and (2) the same species may exhibit a different sensitivity depending on whether it is close to its optimal range or near the edge of it (Brown et al. 1995, Gilman 2006, Findlay et al. 2010). Thus, monitoring of key species is not yet recommended for the MEMP (see Table 3).

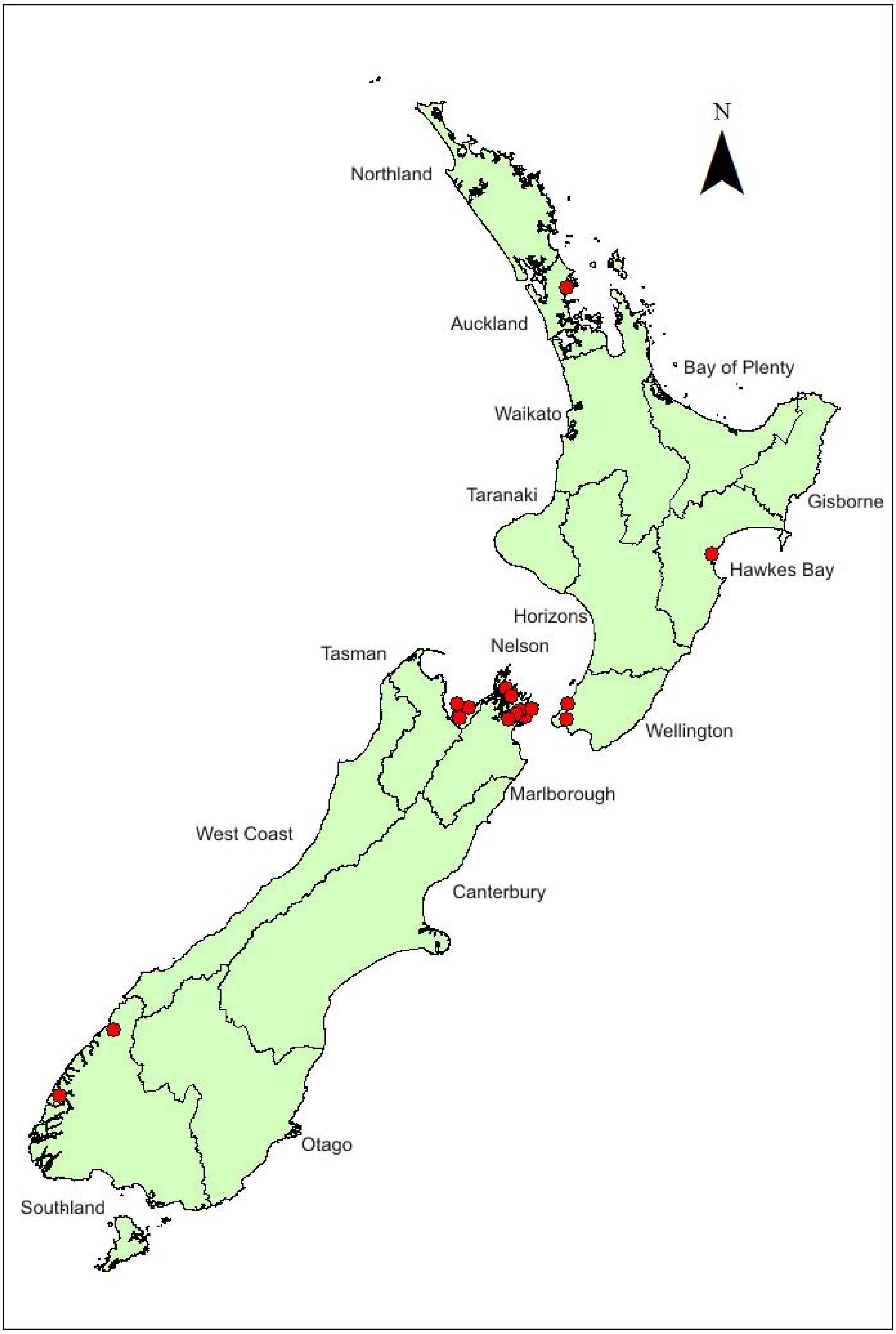

Figure 6: Location of current subtidal soft-sediment community monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

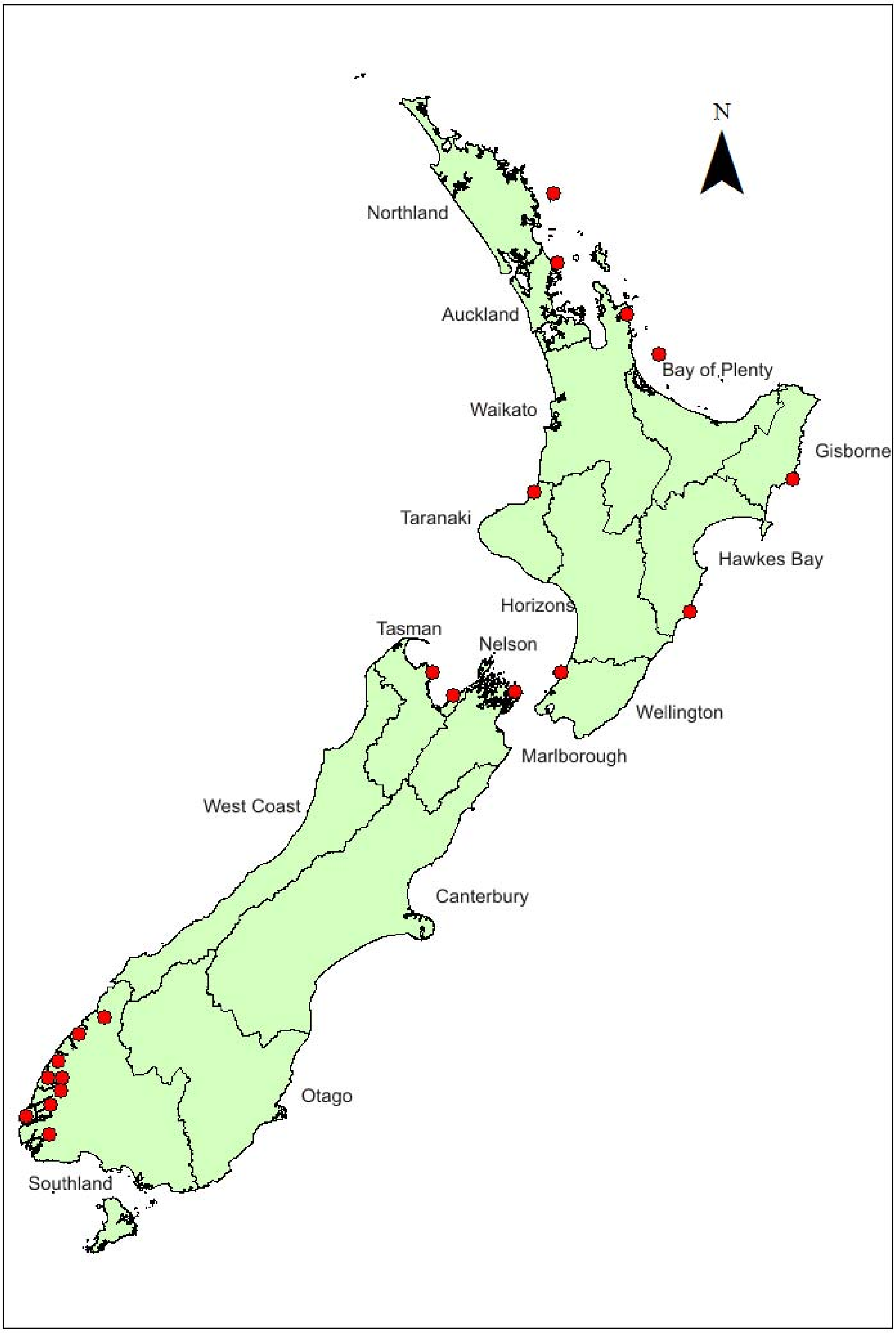

Figure 7: Location of current rock lobster monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand), excluding commercial catch data.

Figure 8: Location of current blue cod monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand), excluding demersal fish trawl sites see Figure 10).

Reef fauna: Fish and larger invertebrates (such as rock lobster and urchins) which live on the reef or mainly utilise it for food and shelter. This is a composite variable i.e., the data can be analysed as community composition, as one of a number of biodiversity measures (e.g., species richness, species evenness) or even as individual species.

Use. Community data for these species can be used to calculate biodiversity indices and contribute to the calculation of ecological integrity and ecosystem goods and services. Changes over time would be of obvious interest to fishers, MPI and DOC. However, there are no studies providing guidelines for assessing reef fish community health. A start on this has been made by splitting the community into "exploited" and "non-target" species and measuring several response variables sensitive to community stability and structure (Wing & Jack 2013).

Responsiveness. Reef fauna are likely to be sensitive to many pressures, especially fishing and changes in water temperature, but, with the exception of harvesting, responses to most pressures are not well understood. A major problem with assessing sensitivity is mobility of these species; not all observations may be of resident fish.

Variability. In the past there were a number of studies of temporal variability, usually in relation to habitat change and oceanographic conditions, mainly in Northern New Zealand (Jones 1988, Denny & Schiel 2001). Recent monitoring of crayfish, sea urchins and the reef fish community in Fiordland has resolved temporal variability and marine reserve effects on a ten year time frame (Wing 2009, Jack & Wing 2013, Wing & Jack 2013).

Degree of monitoring. Many national-level monitoring programmes include reef communities, especially where reefs form a large or socially important part of the marine system (e.g., Great Barrier Reef). In New Zealand, the relative abundance of reef fish and other fauna such as lobsters has been surveyed in many parts of the country but few sites outside marine reserves have ongoing monitoring (Figure 9). Even sites inside marine reserves generally have irregular monitoring.

Methods. Methods vary from diver surveys of transects to baited underwater videos, each with their own problems. Diver surveys limit the size and depth of the areas that can be surveyed and are often biased against more cryptic species. Remote video transects are biased against cryptic species and mobile species frightened by the remote vehicle, while baited videos collect proportionally more scavenging species. In all cases mobility makes it difficult to gain strongly quantitative data, emphasizing the need for replication and long time-series data.

Utility in MEMP. This composite variable performs well on two counts (see Table 3): it can be made use of directly or indirectly in reporting biodiversity, health, ecosystem goods and services and ecological integrity, even though there are as yet no methods for assessing health from the community data; and studies to date suggest that temporal trends can be detected over and above natural variability. It performs less well in terms of known responses to stressors; it is not always part of national monitoring programmes and there is little national coverage within New Zealand. More importantly there are as yet no standard methods accepted across the country, so it is presently not suitable for being included in an MEMP.

Demersal fish communities: Demersal fish are those that are found near the seafloor for all or part of their life cycle. This is a composite variable i.e., the data can be analysed as community composition, as one of a number of biodiversity measures (e.g., species richness, species evenness) or even as individual species.

Use. Data from demersal fish abundance surveys contribute to biodiversity indices and measures of ecosystem integrity, and to economic and cultural aspects of ecosystem goods and services. The data can also be analysed to give the condition of some fisheries and some information on trophic links. However, there has been only one study demonstrating a relationship between demersal fish biodiversity and the biodiversity of any other component of the ecosystem (a non-New Zealand study relating demersal fish to epifaunal biodiversity (Reiss et al. 2010)), suggesting that these data cannot yet be used as a surrogate for ecosystem biodiversity. A broad-scale study across three areas of New Zealand (Chatham Rise, Challenger Plateau and north-eastern Northland) detected no relationship between demersal and epibenthic biodiversity (Hewitt pers. comm.) There are also no methodologies for relating demersal fish community structure to demersal community health.

Responsiveness. Similar to the reef fish discussed above, demersal fish are likely to be sensitive to many pressures, especially fishing and changes in water temperature, but these sensitivities are not generally well understood.

Variability. Temporal variability in stock species is well analysed. Some analyses have been carried out on other species and estimates of biodiversity developed as part of programmes investigating the usefulness of the data for monitoring biodiversity and as indices for benthic health (I. Tuck pers. comm.).

Degree of monitoring. Many fishing nations collect data on demersal fish communities as part of their stock assessment programmes (García-Rodríguez et al. 2011 and references therein). Trawl surveys are generally considered to be an appropriate approach for sampling fish communities in many habitats (Cotter et al. 2009) and a wide range of potential fish-based indicators are available (Rice 2003), which are generally categorised into species-based, size-based and tropho-dynamic groups. In New Zealand, similarly, while information on some specific fish species is available from DOC and university monitoring, demersal fish data come primarily from a consolidated database of trawl surveys held by MPI. Although initially data were collected by different vessels each with different fishing gear; vessel and gear type has been standardised within each area/fishery for many years now (although gear type in particular varies between fisheriess). On all surveys, catch weights of all species are recorded to the lowest taxonomic level possible and length distributions are collected for certain species (with the number of these species increasing in recent years). Surveys are conducted as part of the stock monitoring and assessment process, with the costs recovered from the fishing industry. This has meant that a number of the trawl survey series have been reviewed (Beentjes & Stevenson 2000, 2001, Morrison et al. 2001a, 2001b, O'Driscoll & Bagley 2001, O'Driscoll et al. 2011, Stevenson & Hanchet 2000, Bagley et al. 2013) and as priorities have changed, some historical surveys have been discontinued. Currently, the only routinely conducted trawl surveys are for middle depths areas of the Chatham Rise (annual to date, but moving to less than that) and Southland and Sub-Antarctic (annual to date, moving to biennial) and the inshore areas of the East Coast South Island and West Coast South Island (triennial) (Figure 10). In addition, a rolling triennial programme of surveys is conducted for the four main scampi fisheries, although trawling only forms one component of this work. Deepwater trawl surveys are not considered to have been conducted consistently, or frequently enough to provide standardised indices for monitoring (Tuck et al. 2009). Inshore North Island surveys have been conducted routinely in the past (17 surveys in the Hauraki Gulf since 1964), but none have taken place since 2000.

Methods. The trawl type and codend size vary depending on the fishery the stock assessment is for. Trawl distance and speed vary slightly and are measured on an individual trawl basis. Leathwick et al. (2006a) found trawl distance, codend size and speed to be important predictors of demersal species richness.

Utility in MEMP. This data performs relatively well on three counts (see Table 3). Firstly, it can be made use of directly or indirectly in reporting on biodiversity of demersal fish, trophic structure, ecosystem goods and services and ecological integrity, although it cannot be used as a surrogate for other ecosystem components and insufficient is known to be able to directly relate demersal community composition to the overall health of status of demersal fish communities. Secondly, the methods are consistent within an area (although they differ between areas). Thirdly, this variable is collected in a similar way by many other countries and across a large area of New Zealand's oceans. However, little is known about the responses of demersal fish communities to individual stressors to enable causes of changes to be assessed; nor has temporal variability yet been assessed. However, the extensiveness of the present monitoring suggests that it would be a useful component of an MEMP.

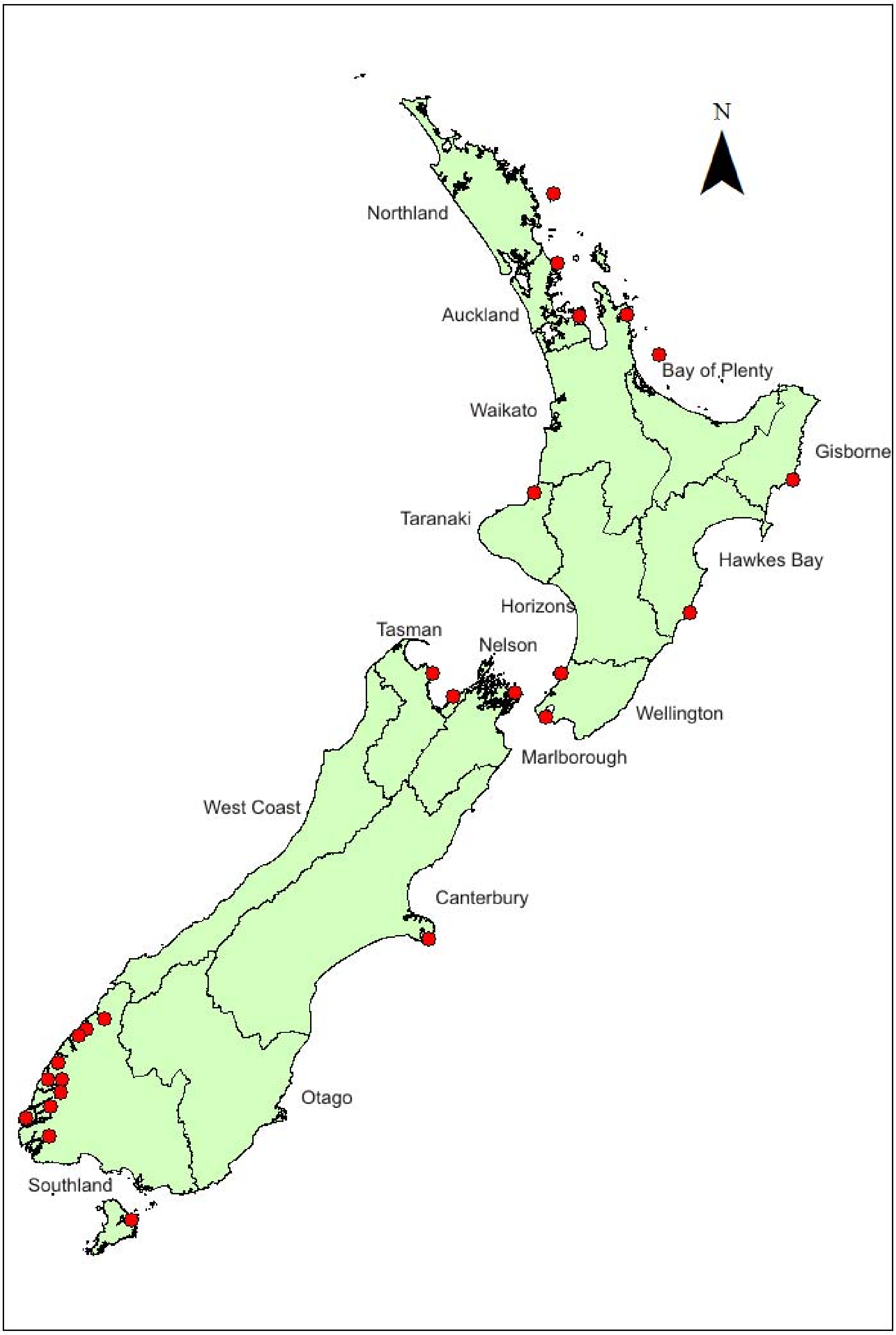

Figure 9: Location of current subtidal reef fish monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

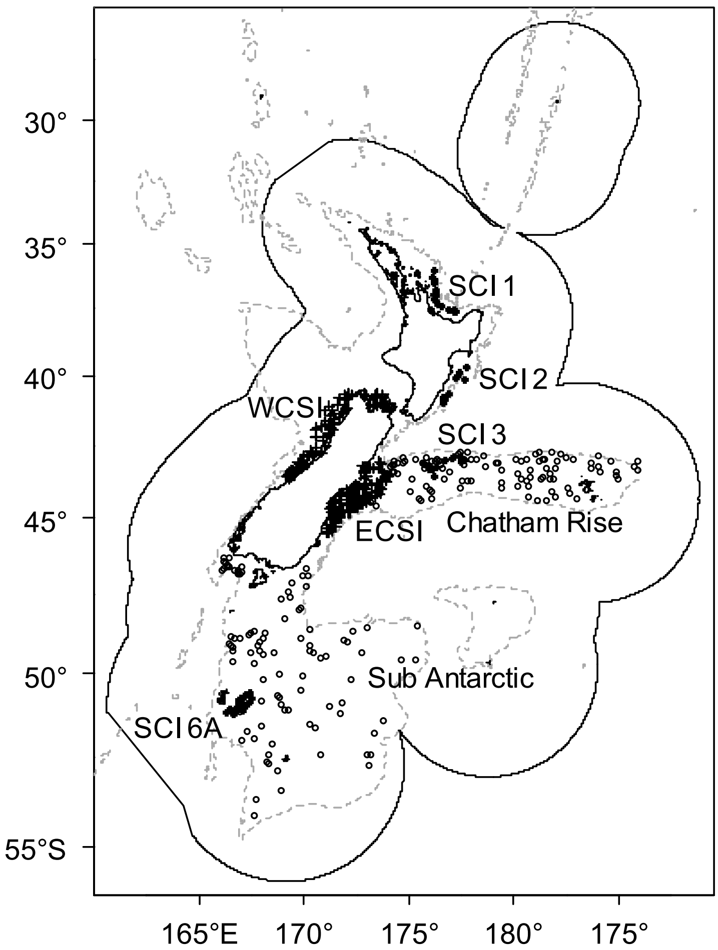

Figure 10: General coverage of trawl surveys (individual stations from one recent year survey plotted for each series). Hollow symbols, middle depths surveys on the Chatham Rise and Southland and Sub Antarctic plateau; solid symbols, scampi surveys (also including seabed photographic component) in SCI 1 (Bay of Plenty), SCI 2 (Hawke Bay and Wairarapa), SCI 3 (Mernoo Bank) and SCI 6A (Auckland Islands); + inshore surveys for East (ECSI) and West (WCSI) Coast South Island.

Zooplankton and phytoplankton: These are generally considered a composite variable i.e., information collected can be at a community level and analysed as composition, as one of a number of biodiversity measures (e.g., species richness, species evenness), or even as individual species (generally the dominants). However, single variable information may also be collected, e.g., total biomass or total cell counts.

Use. Phytoplankton are the foundation of the oceanic food-web, with zooplankton and phytoplankton productivity being key links to higher trophic levels and generally indicative of ocean productivity. Changes in biomass or dominant species of plankton can lead to changes in ecosystem function as these changes flow through trophic levels. There are no methodologies for relating phytoplankton or zooplankton community structures to water body health. Biomass (standing stock) of phytoplankton and zooplankton is frequently used as a surrogate for primary and secondary productivity, respectively.

Responsiveness. There is some information regarding phytoplankton and zooplankton responses to changing temperatures (Batten & Burkill 2010). This is often manifested as a change in the timing of blooms or peak populations (Beaugrand 2005, Chiba et al. 2006, Edwards & Richardson 2004), sometimes for specific species, making it important to collect these data rather than just overall biomass. There have also been documented examples of changes in occurrence linked to changes in seasonal mixed layer processes (Chiba et al. 2012). However, as yet there is little information about the effect of stressors.

Variability. Zooplankton and phytoplankton biomass and species composition generally vary diurnally as many species migrate up and down the water column. They naturally vary seasonally with changes in light and temperature and movement of water masses. All these sources of variation can be important in determining the effect of zooplankton and phytoplankton on higher trophic levels.

Degree of monitoring. There is little monitoring of zooplankton dominants and biomass, or phytoplankton dominants and biomass, in New Zealand, despite these being included in national monitoring programmes in other countries. At international scales, zooplankton and phytoplankton (the latter often measured using colour only) are now mainly measured using a CPR method consistent with the international GACS (Global Alliance of Continuous plankton recorder Surveys). Only one CPR transect is presently monitored in New Zealand (Figure 11), running down into Antarctic waters (although more ships-of-opportunity sampling is being planned). This CPR transect links to international programmes conducted by the US, Australia and SAHFOS (northwest European shelf and the Northeast and Northwest Atlantic, with these regions undergoing monthly sampling). CPR has been recommended as an effective way of monitoring the state of pelagic ecosystems (Beaugrand 2005).

Methods. The CPR zooplankton samples are time consuming/expensive to analyse, as large numbers of organisms must be manually identified and counted by highly skilled personnel. When used as shelf, slope and deep-water indicators of productivity, the assumption has to be made that near-surface productivity is a surrogate for the whole water column as the CPR method only provides information on organisms in the near-surface layer. For any zooplankton or phytoplankton monitoring, sampling needs to be either frequent in time or spatially extensive (Haury 1978) as water masses move, zooplankton are mobile and both phytoplankton and zooplankton have rapid turnover rates.

Utility in MEMP. These variables perform well in terms of usage; they can be made use of directly or indirectly in reporting biodiversity, ecosystem goods and services and are a surrogate for primary and secondary productivity. However, little is known about responses to individual pressures and drivers (see Table 3) (with the exception of temperature) to enable causes of changes to be assessed. Variability is high at fine scales. Once these issues are resolved it would make an important contribution to national MEMP monitoring

4.3 Sediment variables

Sediment grainsize: Particle size distribution of the sediment. This is a composite variable, generally comprising the percentage of sediment (either by weight or volume) found in different size classes.

Use. Changes in sediment grainsize can be indicative of habitat change and type of sediment supply. Increases in mud content can be used as a surrogate for increased sedimentation rates which is specifically targeted for assessment in NZCPS Statement 22. Sediment grainsize is a driver of primary productivity (through its effect on microphytobenthos and macroinvertebrates), nutrient recycling and turbidity (through its effect on resuspension rates) and thus can be used in the calculation of ecosystem services. It is also a strong driver of the distribution and abundance of many macroinvertebrate species and thus can be used to help determine why changes in these may be occurring.

Responsiveness. Changes in sediment grainsize can occur as a result of terrestrial sediment inputs, mining, bottom fishing or dumping of dredge disposal. While in-situ processes (e.g., winnowing of fines by waves) can modify this, such processes may be ineffectual at modifying the characteristics when the supply is large.

Variability. Natural within-year and between-year variability in sediment grainsize has been documented for some intertidal areas (e.g., Hewitt & Hailes 2007), without a strong predictable pattern.

Degree of monitoring. Internationally, sediment grainsize data are not generally collected, except to define sediment characteristics of sites sampled for other variables. Sediment grainsize data are collected intertidally from estuaries in most regions in New Zealand (Figure 12), with a sampling frequency of bimonthly to five yearly.

Methods. Sediment grainsize is measured using a number of standard techniques.

- The longest time series use measurements from sieving, integrated with pipette analysis when differentiation between particles sized smaller than 63 μm is required (e.g., silt and clay from mud). Results can be fuzzy as sieve mesh pores are square, resulting in different sized particles passing through depending on whether they are spherical or elongated. The result is expressed as a percentage by weight.
- In the last decade or so, laser diffraction systems based on the diffraction pattern from a cloud of particles have become available (e.g., the Malvern laser diffraction system) for the entire clay-sand size spectrum (0.5–2000 μm), although not for larger sizes. In these methods, particle size is indirectly measured by relating the angular distribution of scattered light energy to a ‘best fit’ size distribution and the size, shape (assumes spheres) and refractive index of particles all influence the results. The result is expressed as a percentage by volume and its accuracy has been questioned particularly in the fine tail of the particle size distribution.
- Another laser-based system used in New Zealand is the “Time of Transition” laser particle sizer system, where particle size (0.1–2000 μm) is directly measured. This system includes 2-D image analysis technology to derive particle shape and size. The results can be presented as number of particles or percentage volume information.

Utility in MEMP. This composite variable performs well on two counts (see Table 4: usage (it is a surrogate for sediment accumulation and can be used to calculate ecosystem goods and services and ecological integrity); and responsiveness (enough is known about responses to individual stressors to enable causes of changes to be assessed). While the variable is not used in many countries in their monitoring programmes, the variable is measured in many New Zealand estuaries. However, methodological issues are a major problem. Because none of the methods has a clear advantage over the others, research is needed to determine if measured degrees and rates of change are similar across methods.

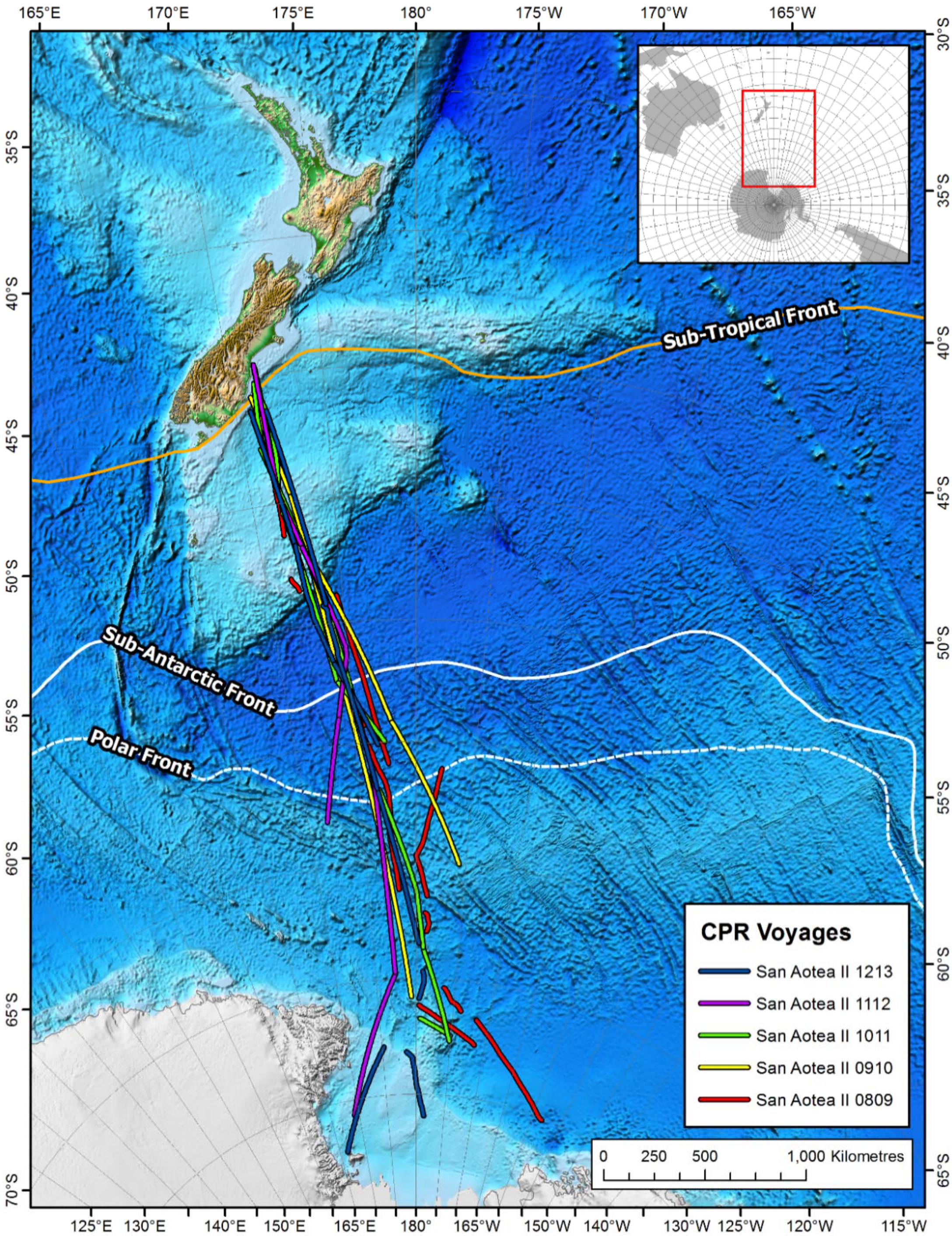

Figure 11: CPR monitoring transects for the last five years.

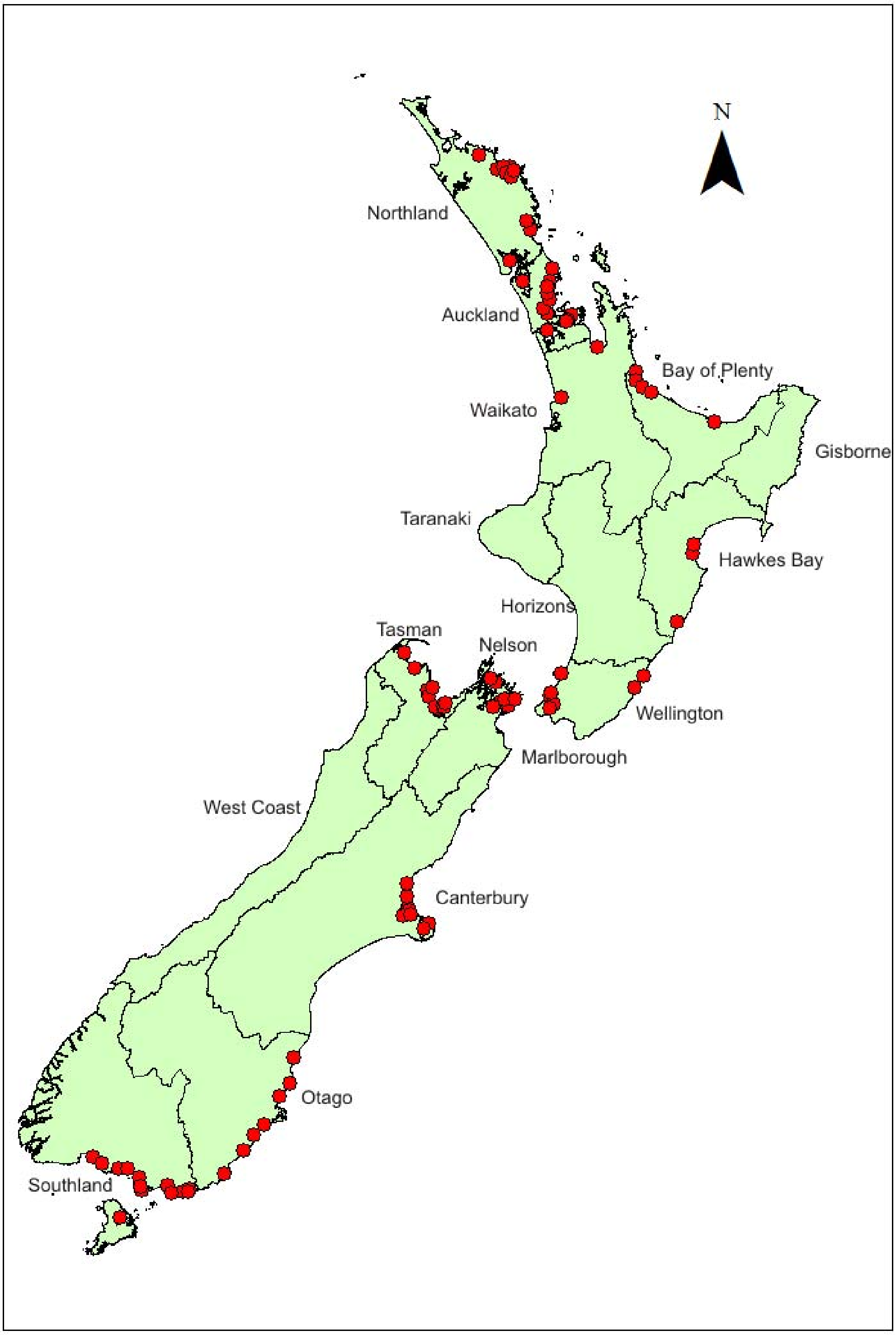

Figure 12: Location of current sediment grainsize monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Table 4: Summary of utility of sediment variables for a national MEMP. Scoring is defined at end of Section 4.1.

		scores as	*max score*	**Sediment grainsize**	**Sediment chlorophyll-a**	**Sediment organic content**	**Sedimentation rates**	**Sediment nitrogen content**	**Sediment metal concentrations**	**Redox depth**	**Sedimentary habitats**	**Erosion of coastal areas**
Use	Contributes to indicators	***1 or 2***	***2***	**2**	**1**	**1**			**1**	**1**	**2**	
	Can assess health	***1***	***1***									
	Surrogate for other ecosystem components	***1***	***1***	**1**	**1**			**1**				**1**
	Specifically mentioned in policy	***1***	***1***	**1**			**1**		**1**		**1**	
	Driver of other components	***1 or 2***	***1***	**2**			**1**		**1**			
Responsive to	Single or multiple pressures	***1 or 2***	***2***	**2**	**1**	**1**	**2**	**1**	**2**	**1**	**2**	**1**
Natural temporal variablity	Does not prevent detection of trends	***1***	***1***		**1**						**1**	
	Unknown	***-1***					**-1**			**-1**		
	High	***-1*** ***-1***	***-1***	**-1**	**1**			**-1** **1**				**-1**
Degree of monitoring	Overseas	***1***	***1***			**1**		**1**	**1**	**1**		
	Spatial coverage of present NZ monitoring	***0–5***		**3**	**1**	**2**		**2**	**2**	**2**		**1**
Methods	Standard method 1 (more than one standard method), 2 (only one standard method)	***1 or 2*** ***5***	***2***	**1**	**2**	**1**		**1**	**1**	**1**		
	Hard to measure accurately	***-1***								**-1**		
	No standard methods	***-1***	***-1***				**-1**				**-1**	**-1**
	No standard definitions	***-1***	***-1***								**-1**	
	Total		***13***	**11**	**7**	**7**	**2**	**5**	**10**	**4**	**4**	**1**

Sediment chlorophyll-a and organic content: Chlorophyll-a is the most common of the six photosynthetic pigments all plants (including microphytes and phytoplankton) use for photosynthesis. Organic content is the total amount of organic matter (live or dead) present in the sediment.

Use. In shallow waters, chlorophyll-a is used as a surrogate for benthic algal biomass (and thus of primary productivity) and is indicative of potential food availability for deposit feeders and some grazers. Organic content is also indicative of food availability and of degree of eutrophication.

Responsiveness. Little is known about the response of either to most stressors, although both these variables should be responsive to nutrient enrichment/eutrophication. Organic content is generally expected to increase with sediment mud content.

Variability. Present analyses of natural variability on Manukau intertidal sandflats suggest that natural (e.g., weather-related cycles) can be separated from changes as a result of anthropogenic factors (Hewitt & Hailes 2007).

Degree of monitoring. Monitoring to guidelines for sediment organic content is done in many countries suffering eutrophication problems. In New Zealand, sediment chlorophyll-a and organic content are also measured, mainly intertidally in estuaries, but from a more limited number of regions than are grain size and macroinvertebrate communities (Figures 13 and 14). Sampling frequency varies from bimonthly to five yearly.

Methods. Chlorophyll-a is measured with a standard methodology but organic content is either measured as total organic content or approximated by the cheaper measure of ash free dry weight (loss on ignition).

Utility in MEMP. Both these variables perform well with respect to usage and response (see Table 4). In estuarine environments, natural variability is understood and there is a moderate amount of monitoring done in New Zealand. Finally, although there are two methods presently used to determine organic content, there is a single standard method for chlorophyll-a. In conjunction with sediment grain size and ecological information, these variables would be useful in an MEMP.

Sedimentation rates: The gross amount of sediment settling from the water onto the seafloor over time.

Use. Sedimentation rates are specifically identified in NZCPS Statement 22 (controls on sedimentation rates). They are also known to affect the distribution and condition of many marine benthic dwelling species.

Responsiveness. Sedimentation rates could be expected to change with changes in terrestrial sediment inputs, dumping of dredge spoil, mining and climate change factors such as rainfall and wave exposure.

Variability. Natural variability is dependent on the sediment source. In deeper areas, remote from the coast, variability will generally be low. In shallower areas, remote from a terrestrial source, variability will be driven by resuspension of the seafloor by waves and currents. In estuaries, variability will be driven by terrestrial inputs, waves and currents. The degree to which natural variability will hinder assessment of change is unknown.

Degree of monitoring. Unfortunately, sedimentation rates are not measured in many places mainly due to methodological problems.

Methods. In the past, four main methods which measure slightly different aspects have been used: sediment traps, rods, accumulation plates or profiling with radio isotopes.

- The traps generally measure gross rates but are adversely affected by the presence of waves, bacterial activity and burrowing organisms. Resuspension can be estimated if paired traps are deployed (e.g., close to the bed and 10 cm above the bed). Trapping efficiency varies as the traps fill, thus requiring frequent servicing (at least monthly in many intertidal areas). These are used in very few locations.

- Rods measure surface elevation changes (net rates) on time scales of weeks to years and are prone to problems associated with scour around the rods by currents and waves at exposed sites. Initially used frequently, these have now generally been replaced by accumulation plates.

- Accumulation plates also measure surface elevation, but results, while unaffected by scour, can be biased if the plates are not buried deeply enough. Sampling frequency varies from quarterly to five yearly. While sediment accumulation plates are relatively cheap, exhibit fewest problems and are used by a number of regional councils and unitary authorities (Figure 15), there has so far been no overall summary of their spatial and temporal variability.

- Profiling with radio isotopes again measures net sedimentation, integrating over a number of sedimentary processes, but requiring expensive laboratory dating techniques. A variety of radio isotope dating techniques are available, covering a variety of time scales from ^{7}Be (days) to ^{14}C (centuries). ^{210}Pb has so far proven to be the most robust, dating sediment deposits up to about 150 years old. Profiles are available from over 20 North Island estuaries, but there is no intention to resample these in the next five years.

Utility in MEMP. While sedimentation rate is specifically mention in the NZCPS, and it is responsive to many pressures, lack of information on natural variability and a standard method preclude this variable as being fit for MEMP purpose (see Table 4).

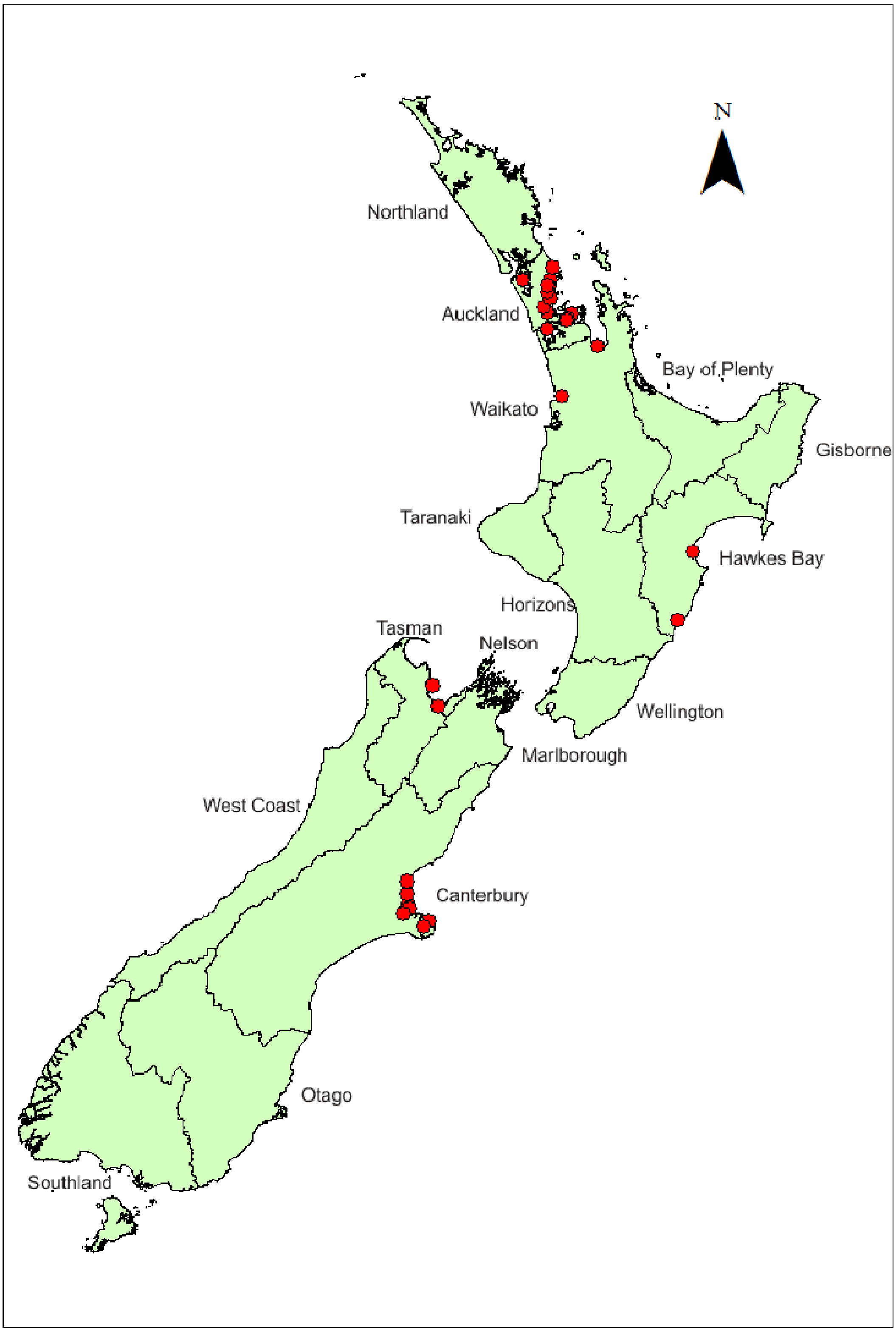

Figure 13: Location of current sediment chlorophyll-a monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

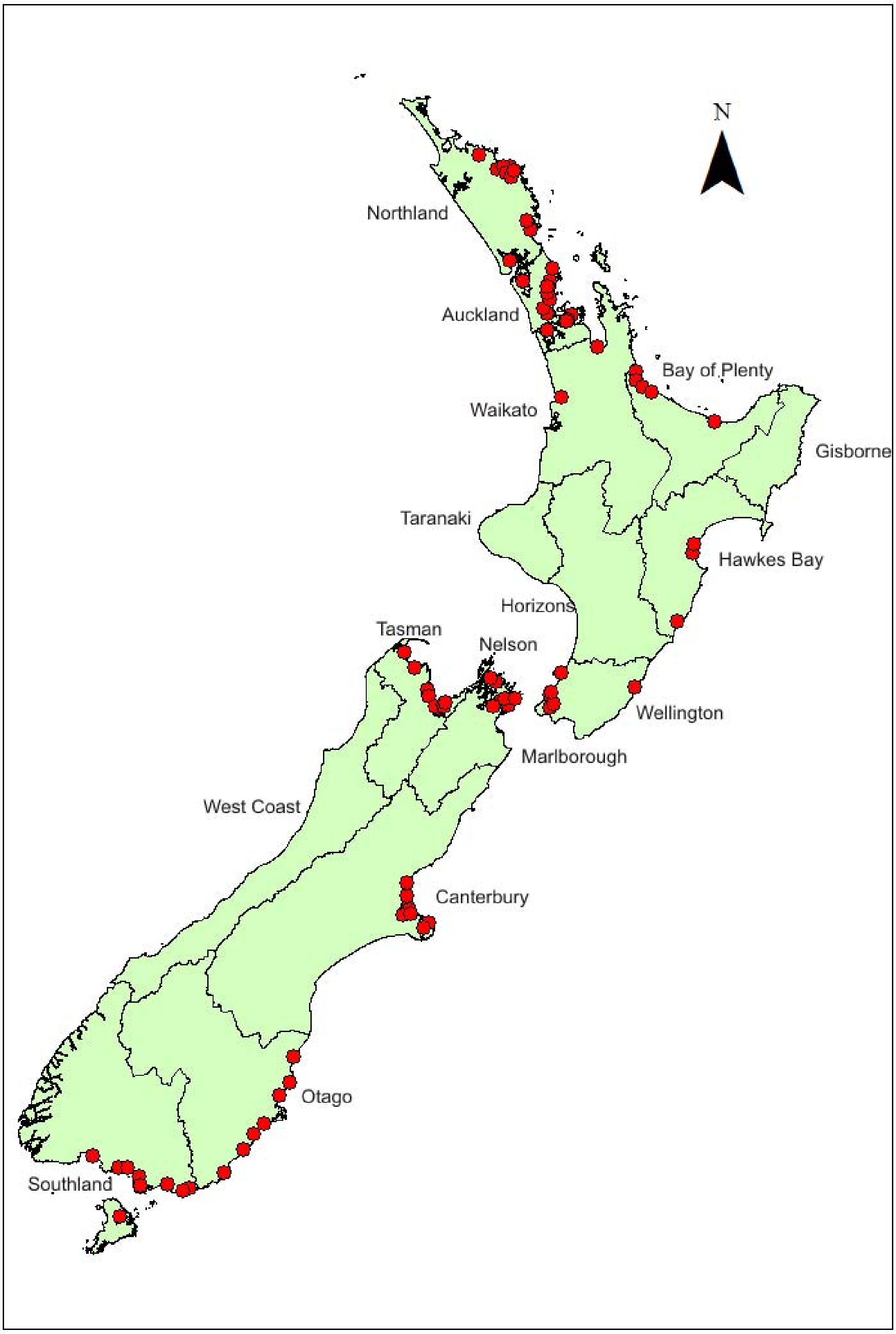

Figure 14: Location of current sediment organic content monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

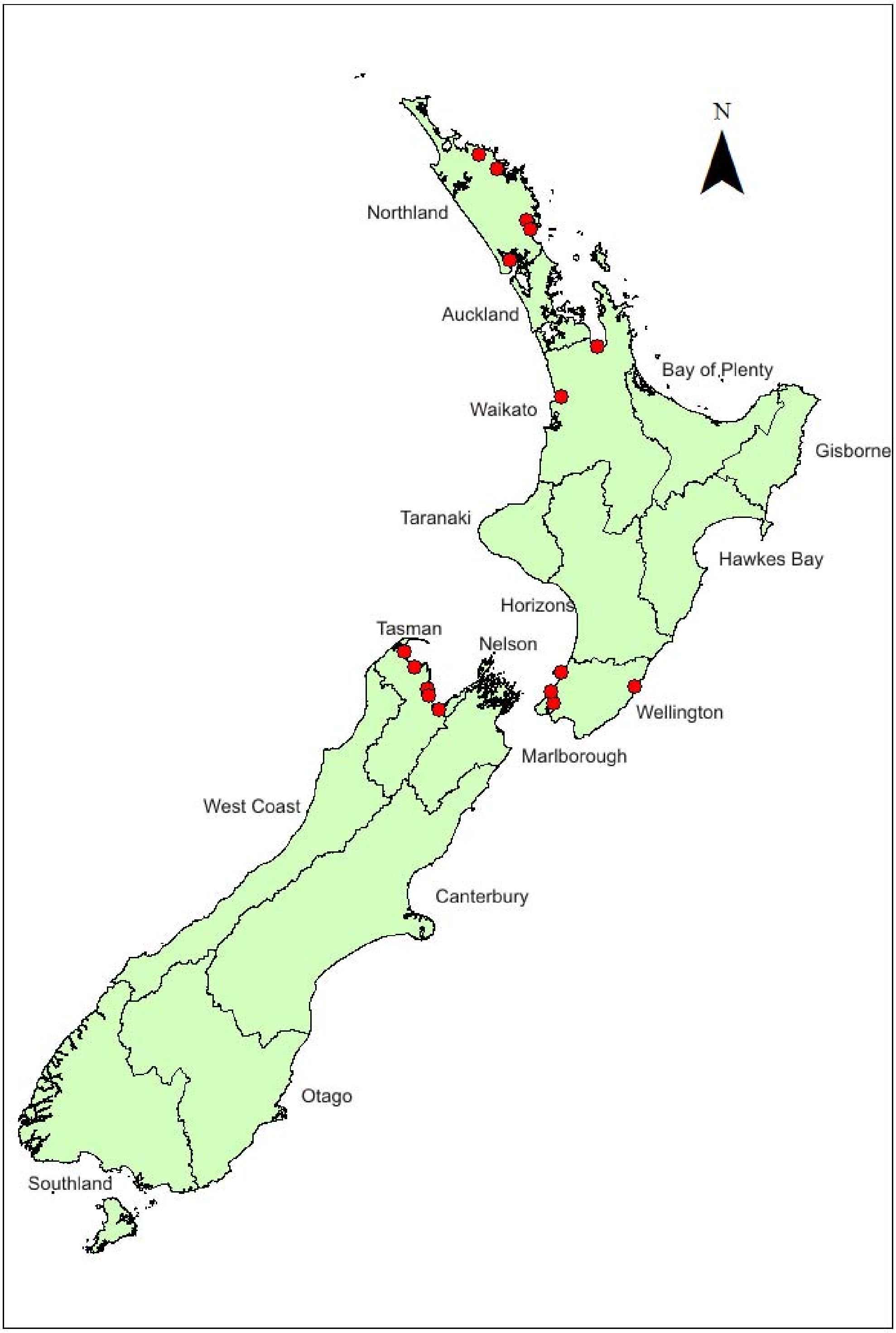

Figure 15: Location of current sediment accumulation plate monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Sediment nitrogen content: A non-specific measure of refractory and labile nitrogen sources.

Use. This is generally used as an indicator of the nutrient loading underlying productivity and food sources, however excessive concentrations are indicative of eutrophication. Guidelines for nitrogen concentrations are still under development for New Zealand, although they exist for other countries. A guideline for total ammonia in sediments has been proposed as part of the current ANZECC guidelines revision process (Simpson et al. 2010; Batley & Simpson 2009).

Responsiveness. Sediment nitrogen content is expected to respond to increases in nitrogen inputs and water column and sediment productivity (eutrophication). There is also likely to be a general increase with terrestrial sedimentation as the amount of fine sediment retained increases.

Variability. Nitrogen content varies naturally with weather and oceanography, making it difficult to determine whether change is a response to eutrophication.

Degree of monitoring. Many countries' national-level monitoring programmes include this variable, especially where eutrophication has been observed. Samples for sediment nitrogen content are collected intertidally from estuaries in most regions in New Zealand (Figure 16), with a sampling frequency that varies from annually to five yearly and analysed by standard methods.

Methods. Nitrogen is expensive to measure, relative to the other sediment variables, however, there are standard methods available.

Utility in MEMP. While this variable has standard methods and is presently monitored in estuaries around New Zealand (see Table 4), it is only indicative of one pressure.

Sediment metal concentrations: Copper, lead, zinc and cadmium sediment content.

Use and Responsiveness. Copper, lead and zinc concentrations are indicative of urban sources of contamination, generally from stormwater. However, boats have recently been highlighted as a significant source of copper contamination (Gadd & Cameron 2012) and copper can also be sourced from agricultural land, either directly or when undergoing urban development. Sources of cadmium can also be urban, although a major source in New Zealand is phosphate fertilizers (superphosphate). Guidelines exist for all of these metals in estuarine and harbour sediments (Warne et al. 2013). The need to avoid adverse effects of stormwater discharges to the coastal environment is specifically mentioned in NZCPS 2010 Statement 23.

Variability. Temporal and spatial variability in all these metal concentration has been analysed from the Auckland Region and trends over time have been able to be identified (Mills & Williamson 2012).

Degree of monitoring. These metals are generally measured in other countries. In New Zealand, data on sediment concentrations of copper, lead and zinc are collected intertidally from estuaries in most regions (Figure 17), with a sampling frequency that varies from annually to five yearly.

Methods. Copper, lead and zinc analyses follow standard methodology with a total extraction from the under 0.5 mm fraction, although in some areas a weaker extraction from the under 0.063 mm fraction is also measured. The weaker extraction from the smaller sediment fraction is thought to be representative of the fraction that would be ingested by macrofauna, and is the fraction likely to be transported around the harbour by currents and wave resuspension. Problems with analytical repeatability for the weaker extraction have been recorded in sediments with low mud content (Mills & Williamson In review). The weaker extraction is also useful for comparing sites with different sediment textures, or where sediment texture changes between samplings. Mills & Williamson (In review) also note that these three metals are generally well correlated with PAH and organo-chlorine contaminants and that between three and five replicate samples are required to adequately assess concentrations. Data on cadmium concentrations is not collected from as many estuaries as copper, lead and zinc, although the range in sampling frequencies is the same, annual to five yearly. Samples for cadmium are collected and analysed by standard methods.

Utility in MEMP. These variables have standard methods and are presently monitored in estuaries around New Zealand. They respond differentially to a number of pressures, particularly those present in coastal areas, and have measured effects on ecology. As their natural temporal variability has so far not precluded detection of trends they would be useful for inclusion in an MEMP.

Redox depth: the depth to which the sediment is oxygenated.

Use. Redox depth is generally used as an indicator of high levels of oxygen stress associated with eutrophication.

Responsiveness. The depth to which sediment is oxygenated responds to oxygen stress associated not only with eutrophication, but also to depositions of algal wrack and cohesive sediments. Moreover, the correlation with eutrophication only holds for sediments not strongly impacted by waves.

Variation. Information on natural temporal variability against which to assess the effect of anthropogenic impacts does not seem have been generated for New Zealand sediments.

Degree of monitoring. This variable is monitored in many international monitoring programmes, although sometimes total organic carbon in the sediment is used instead. In New Zealand, redox depth is measured in many estuarine and harbour intertidal flats (Figure 18), again with a sampling frequency that varies from annually to five yearly.

Methods. Field redox depth measures (depth of the grey-black transition) are problematic being relatively subjective and do not always equate to the oxygen profile measured in a laboratory, particularly for those sediments that are highly bioturbated (turned over by burrowing animals) or have high iron content.

Utility in MEMP. This variable, while frequently measured, is difficult to measure accurately, and is only indicative of oxygen stress under a limited number of conditions. It is not recommended for inclusion in an MEMP.

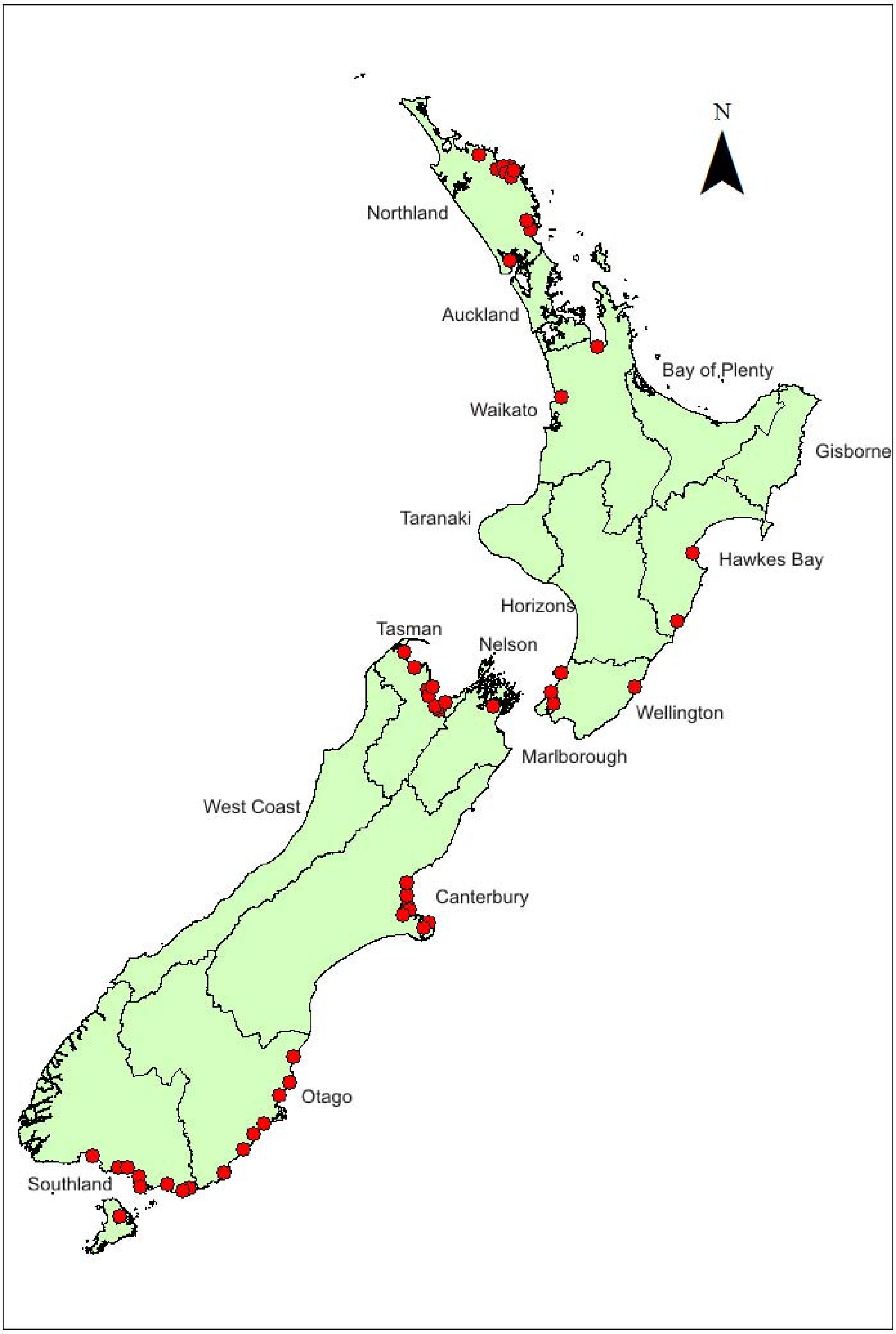

Figure 16: Location of current sediment nitrogen monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

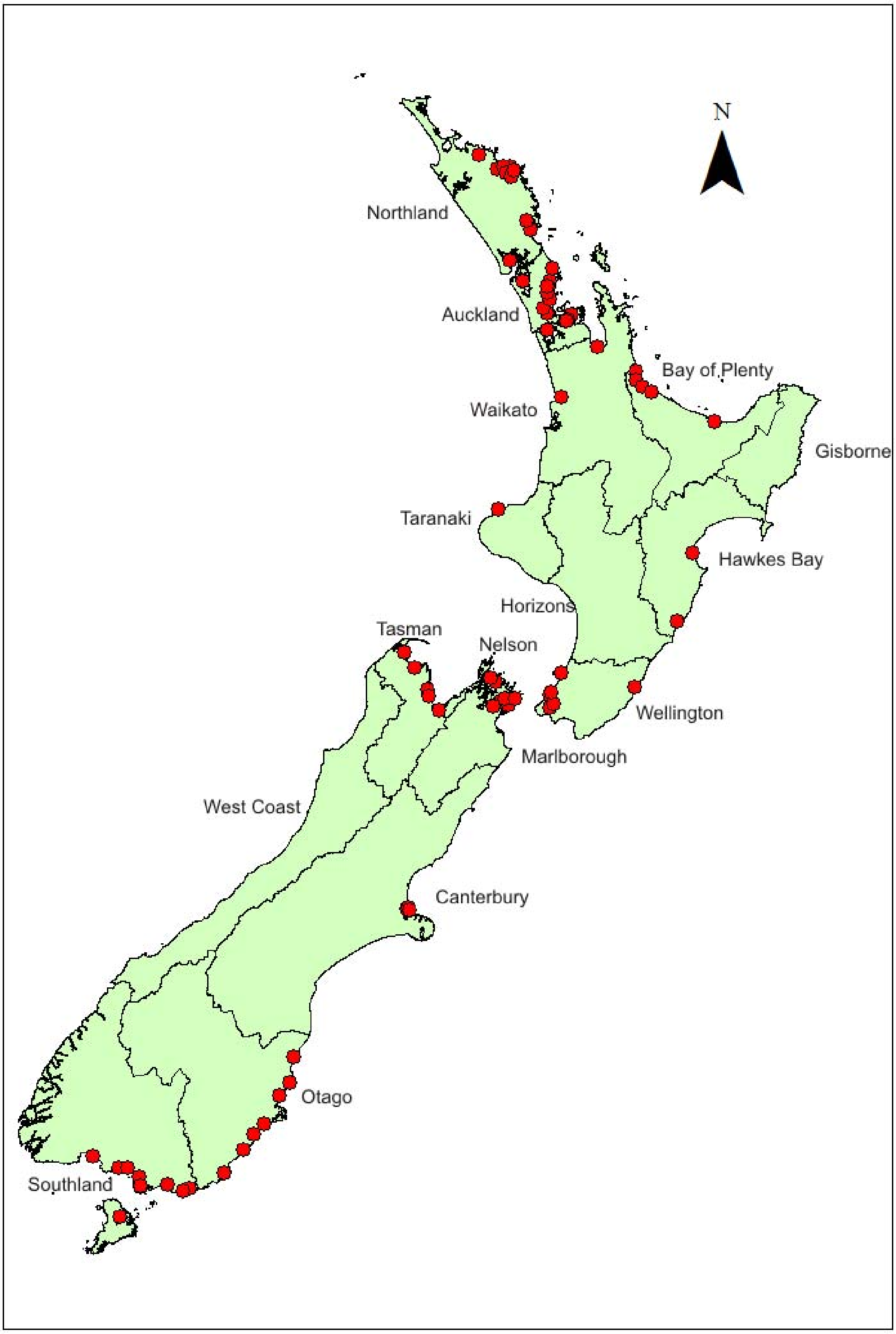

Figure 17: Location of current sediment metal concentration monitoring sites stored in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

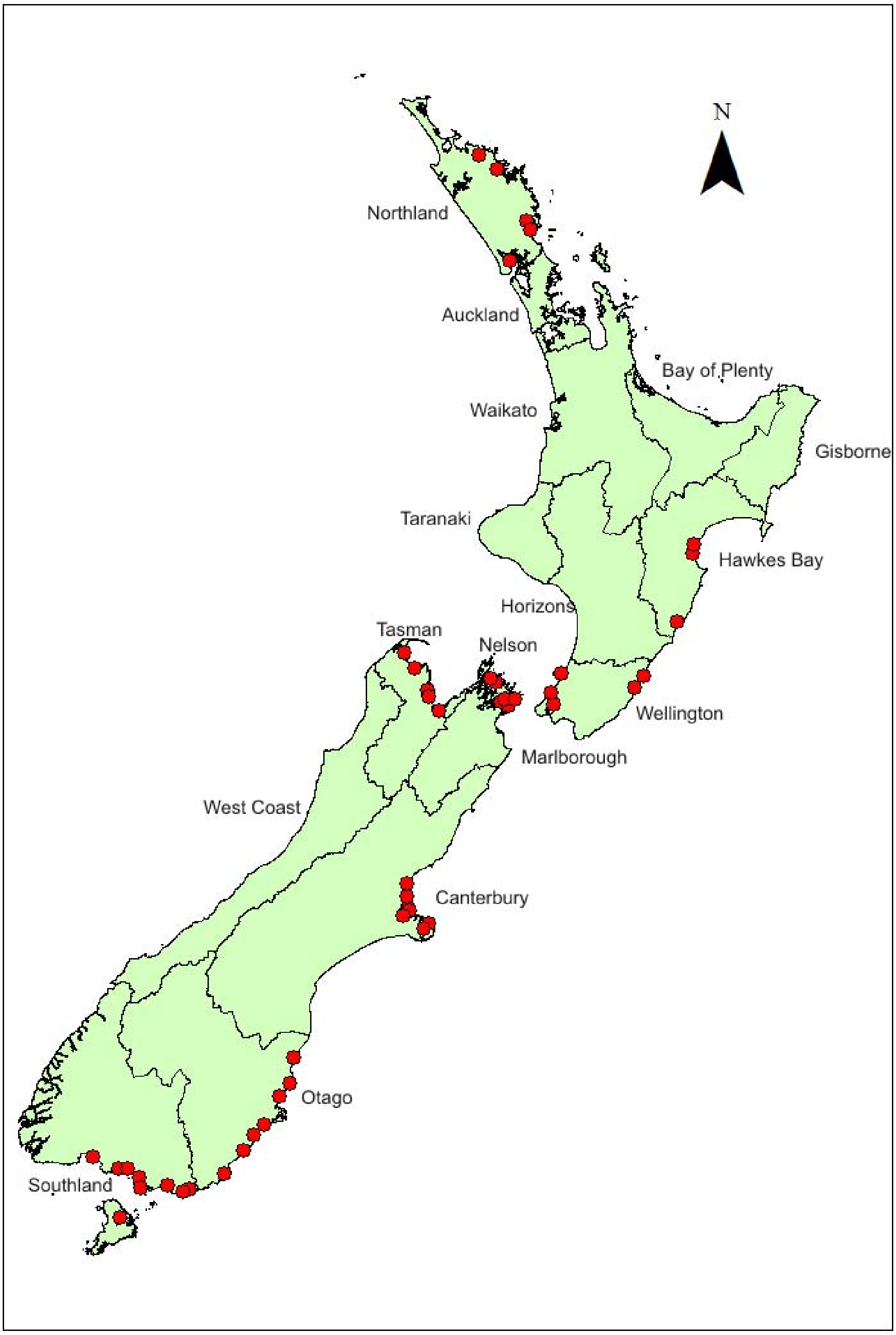

Figure 18: Location of current redox depth monitoring sites stored in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Sedimentary habitats: Habitats defined by broad sediment grainsize categories, (e.g., mud, gravel), generally over large spatial scales (e.g., 10 to 100 km).

Use. Similar to biogenic habitats, changes in maps of sedimentary habitats across an area or at a location would help predict/assess changes in ecosystem goods and services, productivity and nutrient/sediment/oxygen fluxes. Changes in area of mud habitats are also directly useful for reporting on NZCPS Statement 22 (controls on sedimentation rates).

Responsiveness. Changes in sedimentary habitats may occur as a result of bottom trawling, mining, terrestrial sediment inputs, dredging, dumping, and alteration by current and wave patterns.

Variability. Natural temporal variability is assumed to be low due to the low resolution at which these are defined.

Degree of monitoring and methods. Monitoring of sedimentary habitats suffers from a lack of robust criteria for defining habitats. There are two presently available (Department of Conservation & Ministry of Fisheries 2011, Robertson & Peters 2006); the first does not give strong guidance on the sediment definitions, while the second utilises easily assessed field characteristics that do not always relate well to laboratory analyses of particle grain size (Felsing & Giles 2011). These habitats are expensive to monitor as no remote assessment tools are yet available.

Utility in MEMP. This variable would be a useful candidate for MEMP based on use, responsiveness and low levels of temporal variability (see Table 4). Unfortunately, lack of standard definitions and cost-effective methods mean that it is not suitable.

Erosion of coastal areas:

Use and Responsiveness. Beach erosion patterns are expected to change with climate change and natural cycles of different weather patterns seen at decadal timescales.

Variability. Natural temporal variability is high, driven by storm strength and wave direction, suggesting that changes in erosion patterns driven by climate change would be hard to isolate. Moreover, as erosion is rarely allowed to continue without intervention it would be difficult to interpret changes (or lack of them) over time in beach erosion.

Degree of monitoring. Coastal erosion is presently not included in many countries' national-level monitoring programmes. Beach erosion is measured on some beaches (e.g., Tairua, New Brighton see http://www.niwa.co.nz/coasts-and-oceans/nz-coast/coastal-explorer) but generally only where erosion is a problem.

Methods. Measurement is either by video imagery (Cam-Era) or by beach profiling. Cam-Era sites are sampled every half hour, while the temporal frequency of beach profiling varies from quarterly to irregular intervals.

Utility in MEMP. This variable is only expected to reflect one pressure and is not a surrogate for any other components of the ecosystem (see Table 4). It is highly variable, although a recent cost-effective methodology has been developed, and is not monitored in many places. However, reporting change in this variable over time is likely to be useful at a regional and national level associated with natural hazards.

4.4 Water variables

Seawater temperature:

Use and Responsiveness: Temperature is a critical environmental variable affecting species metabolic rates and distributions and net primary production and is hence an important variable to monitor to observe and predict climate-related change to ecosystems.

Variability. Temperature is variable on many temporal scales (daily, annually, multi-year), but preliminary analysis suggests that increases in temperature, possibly related to climate change, can be seen in some areas of the New Zealand marine environment (David Schiel pers. comm.) and overall (Lundquist et al. 2011).

Degree of monitoring. Most countries' monitoring programmes include temperature, often collected throughout the water column, although increasingly a number of countries also monitor sea-surface temperature via satellite (e.g., Japan, France, India all have their own satellites). In New Zealand, sea surface temperature data are available from both satellite imagery, covering broad-spatial scales, and data loggers.

- Satellite imagery from which sea surface temperature can be derived covers the whole of the EEZ collected by the US National Oceanic and Atmospheric Administration (NOAA) (see Uddstrom & Oien (1999) for a valuable summary of products and where to obtain them). Sensors are generally mounted on sun-synchronous, polar-orbiting satellites with an altitude/swath-width such that the EEZ is imaged either once or twice daily from each satellite. There is a 1.1 km resolution NIWA SST archive available from January 1993 to the present, derived from reanalysis of NOAA data (Uddstrom & Oien 1999).

- Data loggers directly measure sea surface temperature at a number of locations around New Zealand's coast (Figure 19). Sampling frequency varies from daily to monthly. Instrument moorings in the coastal region and in the deeper ocean also measure sea surface temperature. Transect information is available for a single transect across the Chatham Rise (2 – 3 times per year) and along the "Munida" transect off the Otago Coast (multiple times per year). The Argo program is a collaborative partnership of more than 30 nations measuring conductivity and temperature profiles over deep (more than 2000 m depth) ice-free ocean areas (see figure 21 in Hurst et al. (2012) to see coverage around New Zealand). The programme started in 2000 with a target resolution of one float for every 3 degrees of latitude/longitude, which it reached in 2006. While it is ongoing, the time period of resampling any specific area/aspect is unknown.

- Measurement of seawater temperature near the seafloor is available for fewer regions of New Zealand. Measurements in some places are available from instrument moorings, research CTD profiles and trawl-mounted CTDs. Trawl-mounted CTD data are collected from randomly selected sampling stations within a fisheries stratum. New Zealand's longest time series of subsurface temperature come from repeat measurements made from container ships on two transects: Auckland to either Suva or Honolulu; and Wellington – Sydney (conducted in a Scripps Institution of Oceanography, CSIRO and NIWA collaboration).

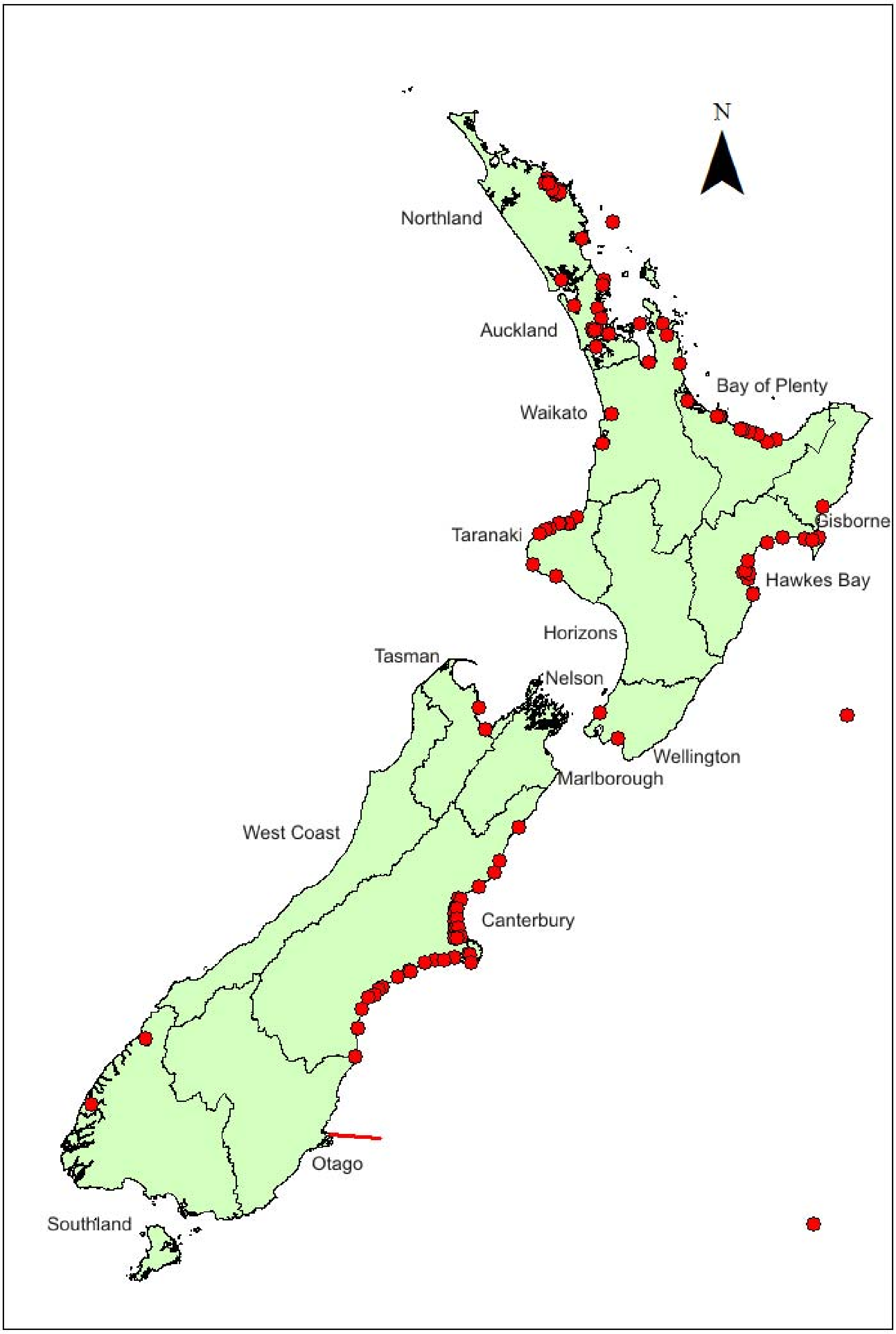

Figure 19: Location of current surface seawater temperature monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Methods.

- As the satellite imagery is derived from overlapping generations of different satellite sensors, verification of consistency in the measurement method in the New Zealand region on some on-going basis is required, and at present this is not happening. The time series is also affected by presence of cloud cover in images (Figure 20). In the New Zealand region, on average, about 1 in 8–10 observations of a given location are clear, although this is regionally variable (e.g., there are often long periods of no data in the winter south of about 55°S).

- Measurement of temperature from data loggers, including CTDs, is a standard technique with no problems, except the potential in some places for the temporal resolution to be low relative to natural variability (e.g., within a month). Trawl-mounted CTD data are primarily collected to assist the fisheries acoustics team post-process fish abundance survey data, with specific sampling stations randomly selected on each time within a survey stratum. These data are therefore really important for process studies, but the randomness of the sampling stations makes assessing changes over time difficult as spatial and temporal changes become confounded.

Utility in MEMP. This variable, while a major driver for some biological responses is only expected to reflect one pressure and is not a surrogate for any other components of the ecosystem (see Table 5). While the data is easily collected over the entire Territorial Sea and EEZ (when there is no cloud cover), it is not clear how expensive ongoing analysis and reporting would be. However, this variable is of prime importance for determining the degree of climate change occurring so would need to be included in an MEMP.

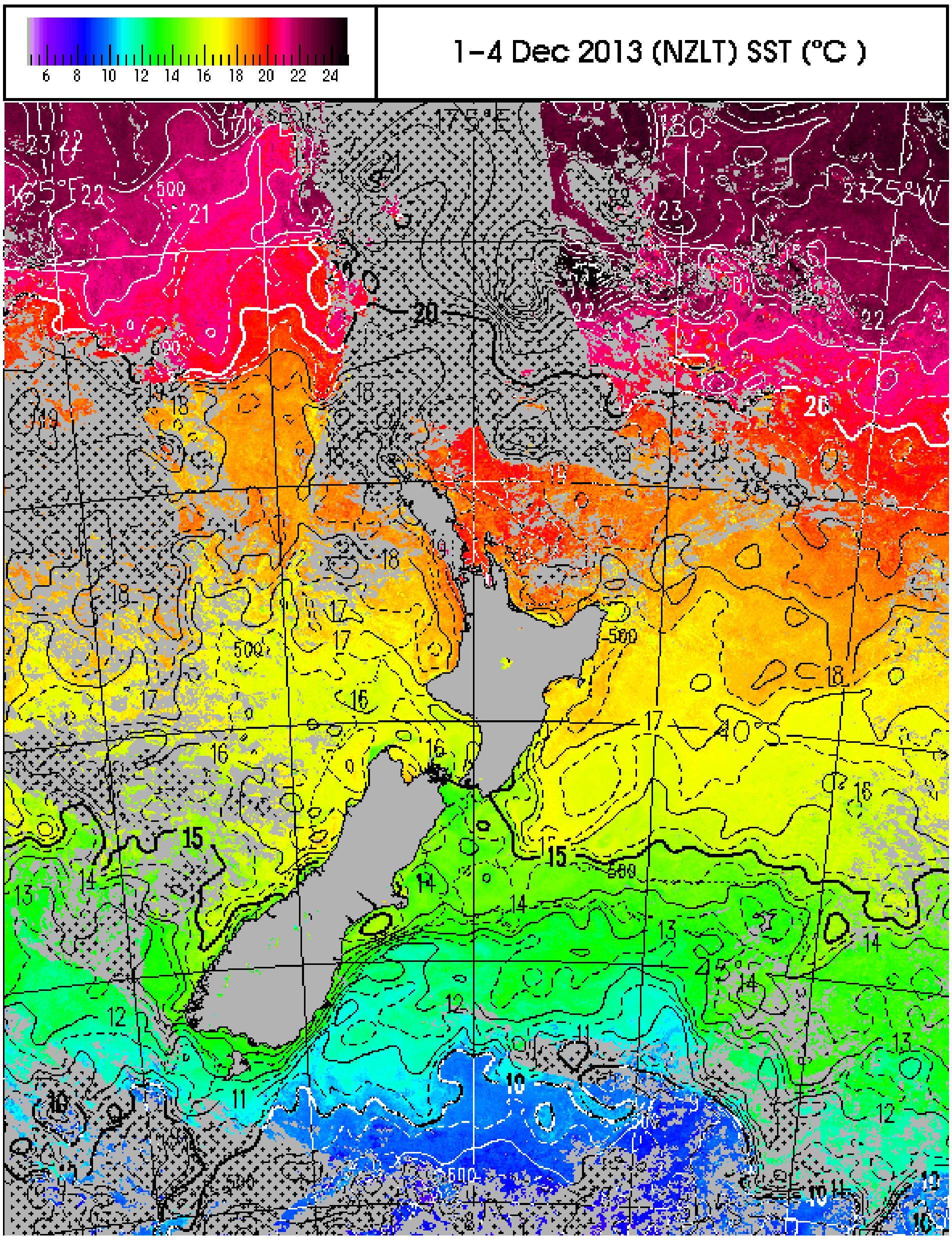

Figure 20: Example of sea surface temperature collected around New Zealand. Grey areas are cloud covered at the time of sampling. NOAA AVHRR satellite data received at NIWA's X-band Lauder satellite receiver, and processed and visualized at NIWA Wellington.

Table 5: Summary of utility of water variables for a national MEMP. Scoring is defined at end of Section 4.1.

Use	Contributes to indicators	*1 or 2*	*2*	1	1	1	1	1		1	1				
	Can assess health	*1*	*1*												
	Surrogate for other ecosystem components	*1*	*1*		1	1									1
	Specifically mentioned in policy	*1*	*1*												
	Driver of other components	*1 or 2*	*1*	1	1	1	1	1			2	1	2	1	1
Responsive to	Single or multiple pressures	*1 or 2*	*2*	1	1	2	1	1	2	2	1	2	2	1	1
Natural temporal variability	Does not prevent detection of trends	*1*	*1*	1	1	1								1	1
	Unknown	*-1*	*-1*									-1	-1		
	High	*-1*	*-1*				-1	-1	-1	-1	-1				
Degree of monitoring	Overseas	*1*	*1*	1	1	1	1	1	1	1	1	1	1	1	
	Spatial coverage of present NZ monitoring	*0-5*	*5*	5	3–5	4	1	1	1	1	1	1	4	1	1
Methods	Standard method 1 (more than one standard method), 2 (only one standard method)	*1 or 2*	*2*	1	2	1	2	2	2	1	2	1	1	1	1
	Hard to measure accurately	*-1*					1		-1	-1					
	No standard methods	*-1*	*-1*						-1						
	No standard definitions	*-1*	*-1*												
	Total		*13*	11	11–13	12	6	6	3	4	7	5	10	6	6

Sea level:

Use. Sea-level rise is expected to be an indicator that integrates the overall rate of climate change globally and regionally. Sea-level rise is expected to affect coastal erosion, flooding (river and storm-tide), tide range, estuary tidal volumes, salinization of lowland streams and groundwater aquifers and species distributions.

Responsiveness. Sea-level rise will respond to global climate change.

Variability. Short-term variation in measurements is driven by the changes in pressure associated with weather systems, and tides. Longer-term variation is driven by both climate change and plate tectonic activity. For example, Bell & Goodhue (2008) comparing the Tararu (Thames) shorter record with Moturiki and Auckland (long records) discovered that relative SLR was higher in southern Firth of Thames, which was later found to be caused by local subsidence of the southern Firth area. Some analyses of long-term sea-level rise have been undertaken for ten datasets, but only the four main ports have sea-level records longer than four decades (Hannah & Bell 2012).

Degree of monitoring. Sea level rise is measured in many countries, frequently as part of a multi-national initiative (Global Sea Level Observing System; GLOSS). In New Zealand, it is measured both remotely by satellite, and by a network of sea level gauges on the open coasts spanning nearly all the ten oceanographic sub-regions of New Zealand (see Figure 21 for location of the oceanographic sub-regions). Within this network, there is at least one maintained sea level gauge located on the coast within in each area, with the exception of the West Coast of South Island and the South Taranaki Bight. Five of these New Zealand stations are part of the GLOSS core network (located in Wellington, Auckland, Waitangi (Chatham Island), Bluff and Scott Base Antarctica). There are also a number of other locations where sea level is measured, frequently in estuaries by Regional Councils (see Figure 21 for location of all sites).

Methods.

- Sea-surface height is measured remotely (Jason 1 and 2 altimetry and previously TOPEX/Poseidon) and is intensively sampled along ground tracks that are 315 km apart (at the Equator) spanning 66°N and 66°S latitude with a complete 10-day repeat of global ground tracks. This information can give both long-term changes and climate variability in sea level and wave height. However, interference ("shadows") from the land result in nearshore measurements being inaccurate or unobtainable at or within a few kilometres of the coastline.

- Reporting of sea level rise in estuaries is complicated by the local effects of riverine, estuarine and oceanic processes. In order to achieve good results a major government initiative would be needed to place a gauge in every major populated estuary/harbour. Along the coast, reporting of sea level rise is complicated by oceanic processes and local plate tectonics, requiring some stratification by detailed analysis of regional uplifting.

Utility in MEMP. This variable is a major driver for some biological responses and a surrogate for risk of coastal erosion. The data can be collected both remotely and at long-term coastal sites. This variable is of prime importance for determining the degree of coastal risk, for both humans and estuarine and coastal ecological systems, associated with climate change so would need to be included in an MEMP.

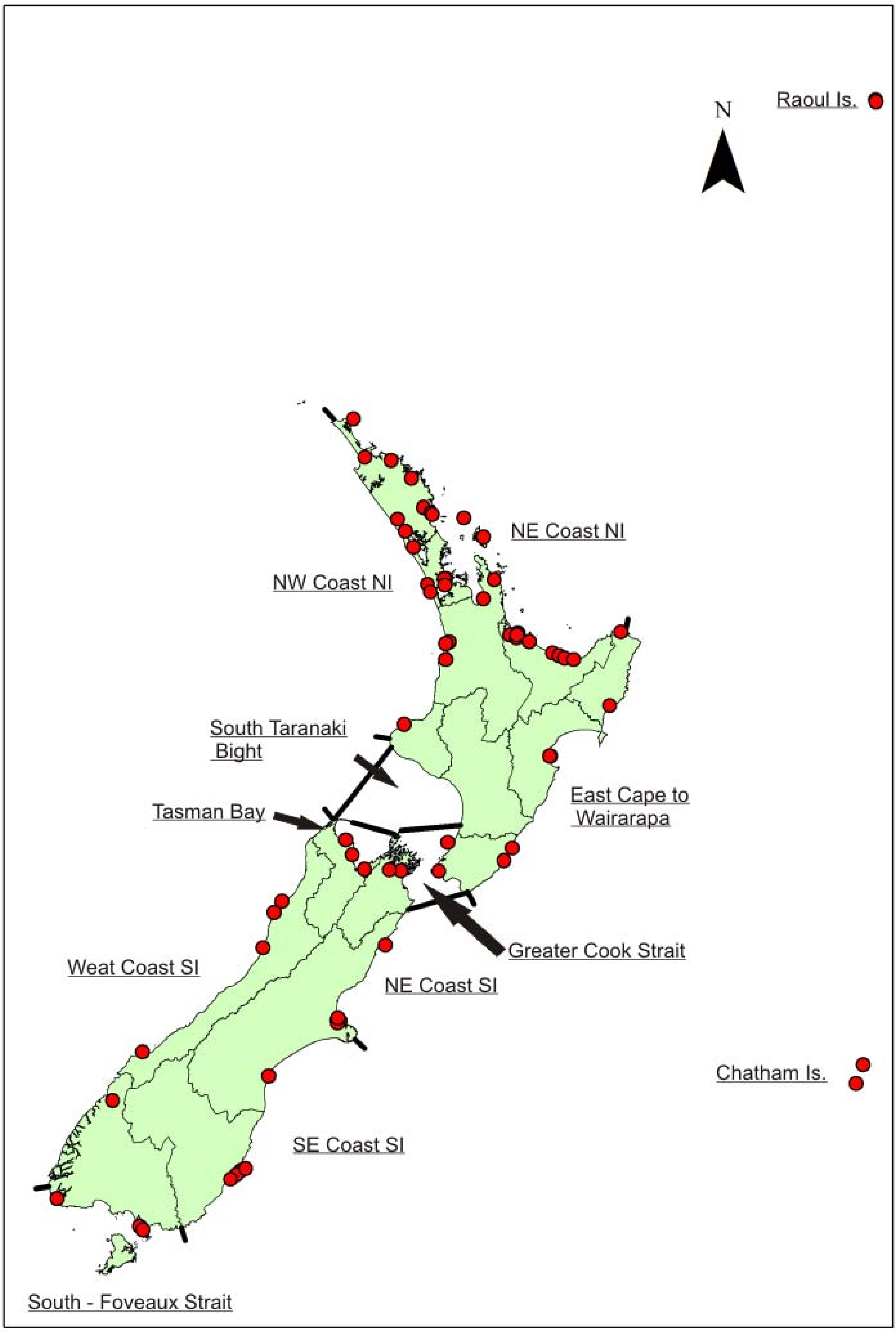

Figure 21: Location of existing coastal sea level monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand) together with the ten coastal oceanographic regions (with breaks between them marked by solid lines near the coast) used for sea level stratification around the main islands of New Zealand.

Chlorophyll-a in the water column: Chlorophyll-a is the most common of the six photosynthetic pigments all plants (including microphytes and phytoplankton) use for photosynthesis.

Use. Ocean chlorophyll-a, like sediment chlorophyll-a, is related to primary productivity (the generation of organic matter via photosynthesis). Estimation of phytoplankton biomass and net primary productivity using satellite-derived chlorophyll-a and SST (see Behrenfeld & Falkowski 1997, Campbell et al 2002 for a review of methods) is widely used for management and research purposes at moderate to large spatial (tens to thousands of kilometre) and temporal scales (seasonal to decadal). See Forget et al. (2009) for examples of applications related to climate change, ecosystem variability, fisheries productivity, stock assessments, fish harvesting and marine aquaculture(Tuck et al. 2014, Pinkerton et al. 2014) recommend chlorophyll-a as a robust long-term monitoring tool for climate-associated changes in offshore ocean productivity. In near-shore environments, the relationship between water column chlorophyll-a, primary productivity and nutrients is more complicated as productivity by the benthos is important and rates (rather than standing stock which is what chlorophyll-a is a surrogate for) also increase in importance.

Responsiveness. In the open ocean, chlorophyll-a is an integrator of changes in nutrients, oceanography and water column biology and responds to eutrophication.

Variation. Some temporal analysis of broad-scale patterns across the EEZ has been undertaken (Murphy et al. 2001, Pinkerton et al. 2005) and predictions associated with climate change have been made (Boyd & Law 2011).

Degree of monitoring. Most countries' national-level monitoring programs include water column chlorophyll-a, frequently at varying depths through the column, although increasingly sea-surface chlorophyll-a is monitored from satellites. In New Zealand, sea surface chlorophyll-a information is available, from ocean colour satellite sensors, across the EEZ (e.g., Figure 22). Finer spatially resolved measurements of chlorophyll-a are also taken in many locations (Figure 23, see Section below on water chemistry for details).

Methods. Earlier measurements are of lower quality compared to those from present satellites, so direct comparisons over time have to be made with care (Tuck et al. 2014). The records since 1997 contain data from two different ocean colour satellite sensors (Tuck et al. 2014); OrbImage Sea Viewing Wide Field-of-view Sensor (SeaWiFS, 4 km resolution) covering September 1997 to 2010; and the NASA Moderate Resolution Imaging Spectroradiometer (MODIS-Aqua 1 km resolution generally with some higher resolution nearshore products available), providing data from 2002 to present. This provides a two year overlap which aids in making comparisons over time. Satellite data availability is also limited by cloud cover and often monthly composite images are used (although care has to be taken in determining the time to composite over due to the potential for there being different quantities of data from different areas). The accuracy of the satellite based method (within about 35%, see below) is much less than in situ methods and periodic validation is required to ensure consistency between different satellite sensors. While conversion of colour data to chlorophyll-a is relatively straight forward in New Zealand oceanic (offshore) waters (Pinkerton et al. 2005), it is more complicated in nearshore waters due to the presence of suspended sediment and coloured dissolved organic matter (CDOM). Highly-reflecting phytoplankton-detrital material can also invalidate satellite-derived standard chlorophyll-a products. Algorithms to allow ocean colour data to be used to assess chlorophyll-a in New Zealand's coastal waters require a regional approach and are being developed using regional biological data. Methods have been tested in the Hauraki Gulf region and South Taranaki Bight in New Zealand, with 38–44% variance of in situ measurements of chlorophyll-a explained (Pinkerton et al. 2013a,b). Further validation of this method of calculating chlorophyll-a in such optically-complex nearshore waters (referred to as Case 2 waters) elsewhere in New Zealand coastal waters is required.

Utility in MEMP. This variable is a major indicator of primary productivity in oceans and will integrate changes in oceanography associated with climate change. While the data is easily collected for surface waters over the entire EEZ (when there is no cloud cover), it is not clear how expensive ongoing analysis and reporting would be. Moreover, in order to be used for the Territorial Sea, verification of coastal optical properties would be required. However, if ocean surface primary productivity is considered to be highly important (e.g., if aquaculture and fisheries is demonstrated to be limited by surface primary productivity), this variable should be included in an MEMP.

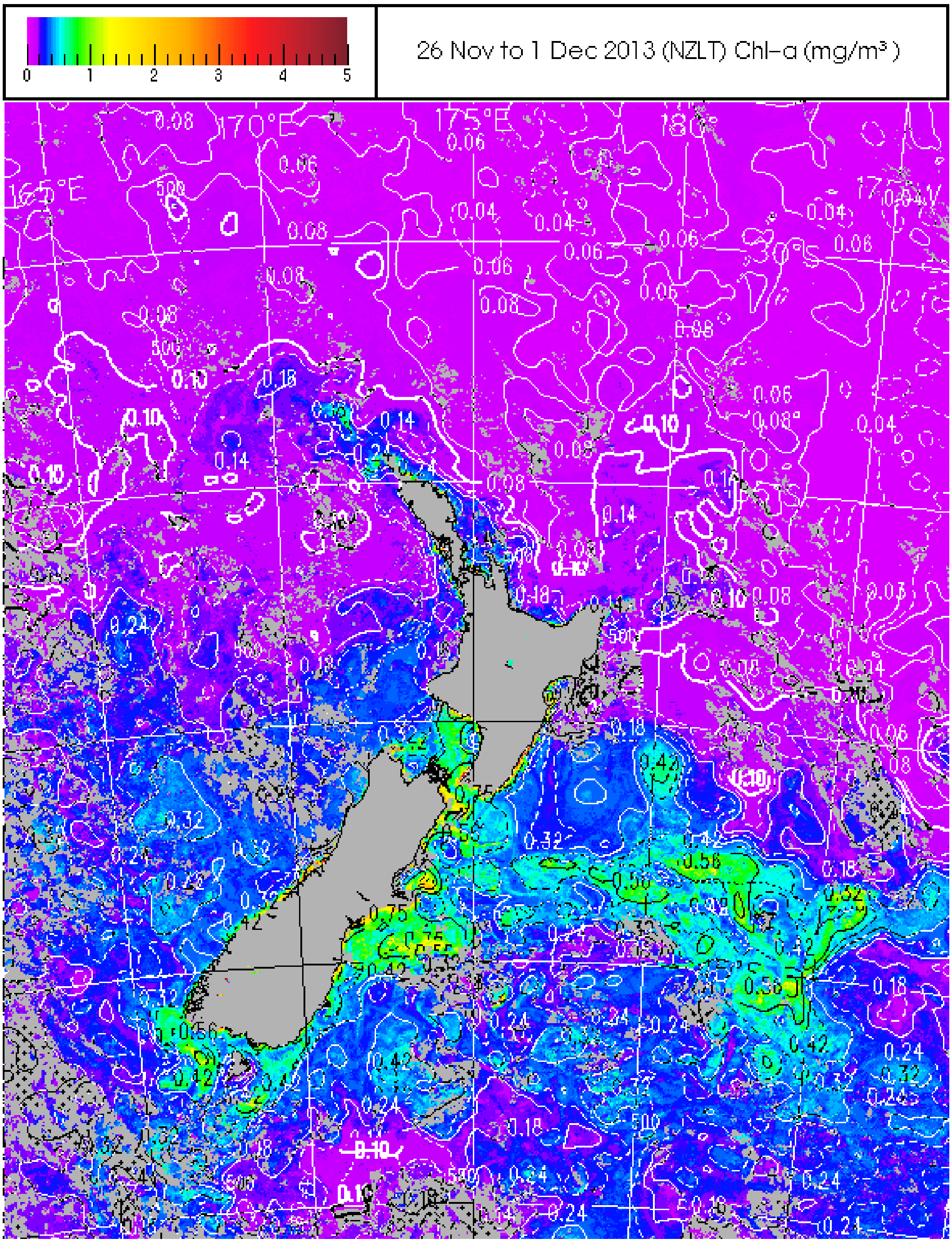

Figure 22: Example of sea-surface chlorophyll-a around New Zealand, derived from satellite imagery. NOAA AVHRR satellite data received at NIWA's X-band Lauder satellite receiver, and processed and visualized at NIWA Wellington.

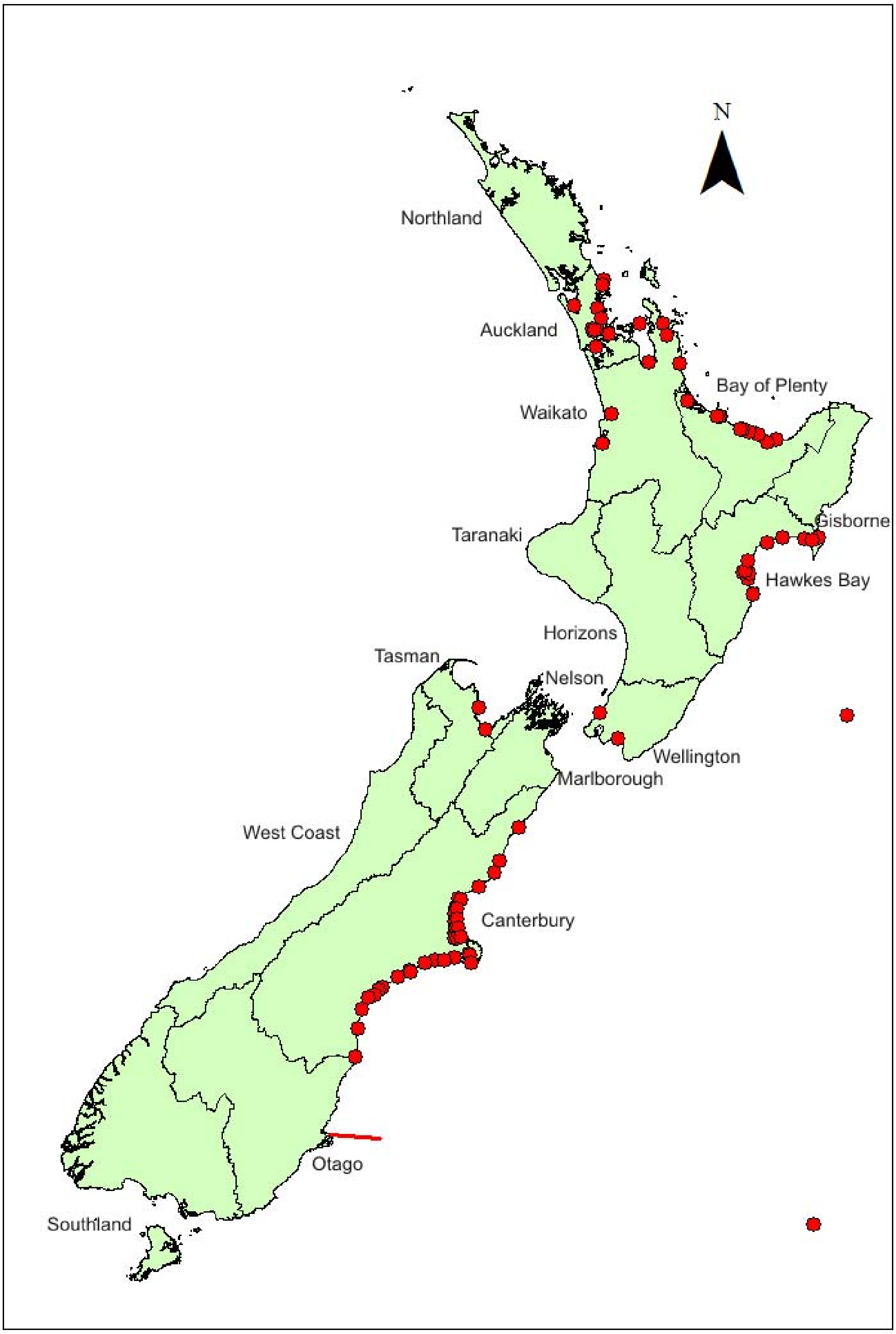

Figure 23: Location of current monitoring sites stored in the meta-data catalogue where point measurements of water chlorophyll-a are made (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Water chemistry: This section covers measurements of the carbonate system to document acidification (pH or pCO_2), oxygen content, and ammonium, nitrate/nitrite and dissolved inorganic carbon (DIC) concentrations.

Use. Decreasing pH (as a result of increasing pCO_2) has a major influence on organism functioning. Ammonium and nitrate/nitrite concentrations in the water column have a major influence on water column primary productivity and are affected by eutrophication. Like pH, dissolved oxygen has a major influence on animal physiology and also affects the rate of nutrient fluxes between the seafloor and the water column. The lowering of pH and carbonate saturation results from increasing atmospheric CO_2 concentrations. Dissolved inorganic carbon (DIC) in seawater can buffer changes in the pH and also varies with seawater pH. Therefore both water quality variables tend to be measured when measuring anthropogenic ocean acidification.

Responsiveness. Increasing pCO_2 results from the increase in atmospheric CO_2 due in part to increasing anthropogenic emissions, and other environmental stressors, in particular terrestrial nutrient and carbon inputs. Increasing carbon dioxide in the ocean has already resulted in measurable acidification (Bostock et al. 2011, Gattuso & Hansson 2011). A dramatic reduction in dissolved oxygen concentrations frequently occurs with eutrophication, the latter being the reason why it is a major focus of monitoring in Europe. Carbonate and DIC availability are sensitive to ocean acidification, and also to terrestrial nutrient and carbon inputs.

Variation. The complicated relationships between pCO_2, dissolved oxygen, ammonium, nitrate/nitrite and DIC and their responses to temperature, acidification and eutrophication will make it difficult to assign a cause to observed changes in coastal waters.

Degree of monitoring. Most of these variables are monitored in many countries' national-level monitoring and some international programmes. In New Zealand, water chemistry measurements are made at a number of spatial and temporal resolutions, varying from spot measurements (single point, single time) by instrumented moorings (single point, fine temporal resolution), to transect measurements (fine spatial resolution, single time).

- Spot measurements for pH, ammonium, dissolved oxygen and nitrate are made by many regional councils and unitary authorities (Figures 24, 25, 26 and 27). These are generally made in the top 0.5 m of water, although sometimes are also collected at 5 m depth as well. Sites are sampled multiple times per year, varying from monthly to quarterly, although in some cases not all sites are sampled each year.

- Water chemistry data are also collected by instrument-based moorings in a few places (Figures 24, 25, 26 and 27). Over the past few years, some Regional Councils and Cawthron, in collaboration with the Monterey Bay Aquarium Research Institute (MBARI), have developed and deployed monitoring platforms collecting meteorological data (winds, air temperature), currents, conductivity, water temperature, turbidity and chlorophyll, (occasionally dissolved oxygen and coloured dissolved organic matter). These are generally shorter time series than the NIWA buoys: two deep ocean buoys to the north and south of the circum-global Subtropical Front which have been deployed since 2000; a large coastal buoy deployed in the Firth of Thames since 1988; and a large coastal buoy deployed off Tutukaka between 1988 and 2005. The Firth of Thames buoy has both nitrate and oxygen sensors in addition to optical sensors (light levels (PAR), chlorophyll-a, temperature and salinity). The NIWA deep ocean buoys measure light levels, chlorophyll-a, temperature and salinity and particle flux. Other chemical monitoring (oxygen, nutrients, particulate and dissolved organics and inorganic compounds, pH and DIC) and biological monitoring (microzooplankton, bacteria and phytoplankton concentrations) has been done by regular vertical profiling at these sites over the last 12 years during ship visits to the buoys. The larger coastal and ocean buoys typically have instrumentation at the surface, mid-water and near the bottom, whereas smaller systems deployed in shallower waters typically measure these parameters near the surface. While more mooring based collection would be advantageous, due to the continuous rather than single time-point nature of the data collection, such moorings are expensive to purchase and maintain and their locations for future monitoring would need to be carefully chosen. At present, new moorings are frequently placed to provide regional scale information, rather than having a national focus. A more strategic view has been recommended for development in conjunction with IMOS, NIWA and Cawthron in association with Regional Councils (Ellis et al. 2012).

- At a broader spatial scale, monitoring of temperature, salinity, pCO2, total alkalinity, dissolved reactive phosphate, silicate, nitrate and chlorophyll-a has been carried out along a single transect ("Munida"), including Subantarctic, modified subtropical and neritic waters off the Otago shelf for 15 years (Currie & Hunter 1999, Currie et al. 2011) and this programme is on-going. For the last five years, temperature, salinity, dissolved reactive phosphate, silicate, nitrate, DIC, particulate inorganic and organic carbon and nitrogen, bacteria, phytoplankton, chlorophyll-a and zooplankton have been collected along a transect across the Chatham Rise. Measurement capabilities on RV *Tangaroa* have been enhanced to provide routine, automatic monitoring of near-surface temperature, salinity, pCO_2 and dissolved oxygen. Uncalibrated information on chlorophyll-a, particle backscatter and CDOM can also be obtained from a ship-mounted Wetlabs Ecotriplet. While the spatial coverage would be limited to the track of the ship, as with all ship of opportunity measurements, the repeat nature of many of the voyages could in the future provide regular spatial data from specific coastal and ocean regions. Finally, ARGO floats collect conductivity profiles over deep (more than 2000 m) ice-free ocean areas in every 3 degrees of latitude/longitude (www.argo.ucsd.edu) but the time period of resampling any specific area/aspect is unknown.

- No time-series of dissolved inorganic carbon in New Zealand waters was found in the meta-catalogue, except for the Munida transect.

Methods.

- Problems with spot measurements of pH include use of probes that are not sufficiently sensitive or properly calibrated and non-skilled personnel not recognising measurement errors (e.g., poor calibrations, probe drifts). Furthermore, measurement of pH must be combined with one other carbonate parameter (alkalinity, total DIC or pCO_2) plus salinity and temperature, or it does not provide useable information on carbonate parameters (e.g., carbonate saturation states). Ammonium and dissolved oxygen are measured with standard consistent methods, as is nitrate, although sometimes nitrate plus nitrite are measured. The latter is not usually a serious problem for making comparisons between different databases, as the nitrite concentration in New Zealand waters is low.

Utility in MEMP. These variables are likely to be more important coastally than in the ocean, where they are affected by a number of pressures. Although standard methods exist, they often require expensive techniques and highly skilled personnel to make the measurements (see Table 5). However, it is likely that coastal and ocean water chemistry is likely to become an increasing concern with global acidification and increasing organic and nutrient loadings occurring. These variables could form an important component of an MEMP once further research has been conducted into the development of cost-effective techniques, the effect of acidification on oceanic trophic food webs and important species and the degree of natural spatial and temporal variability.

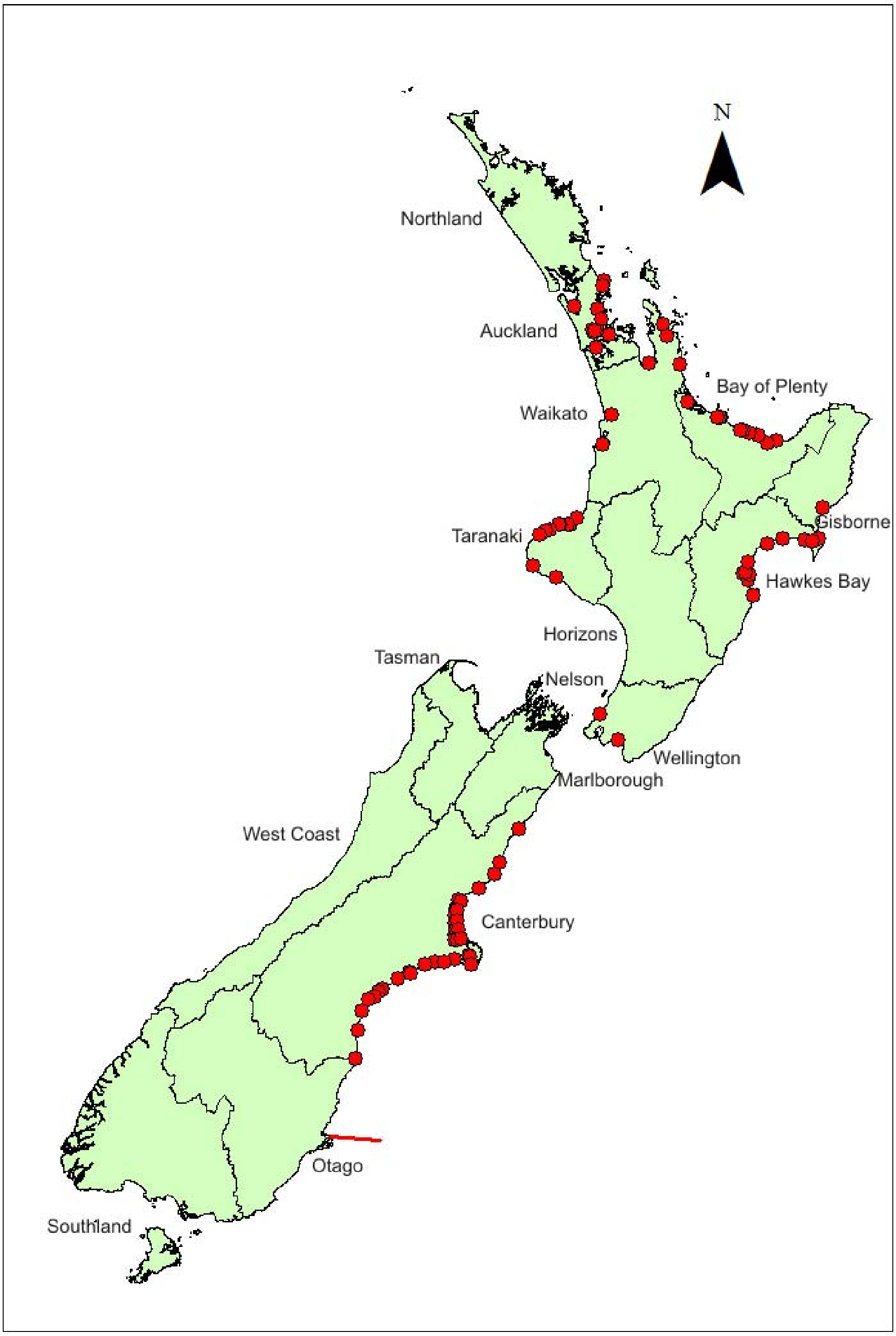

Figure 24: Location of current seawater pH monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

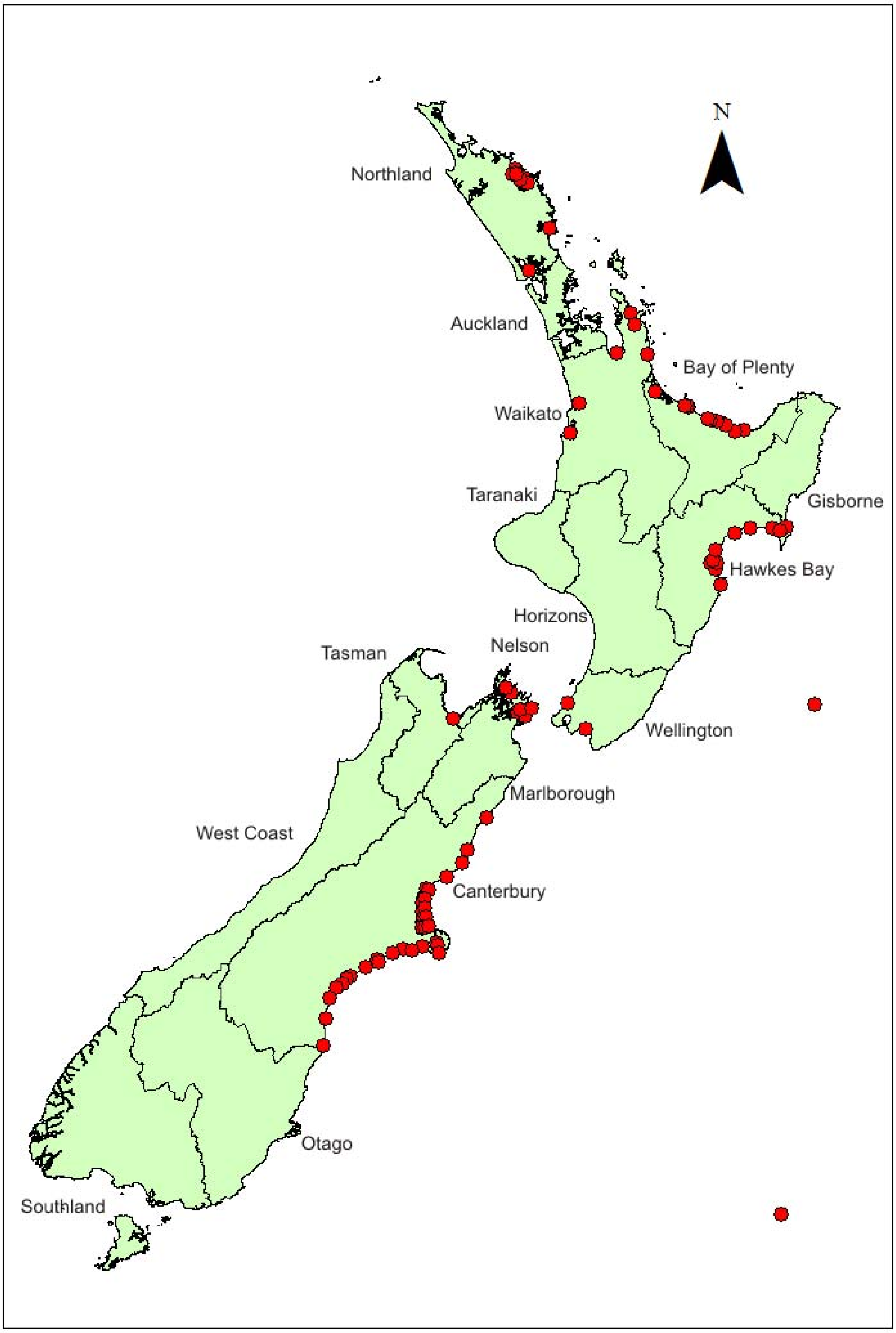

Figure 25: Location of current seawater ammoniacal-nitrogen monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

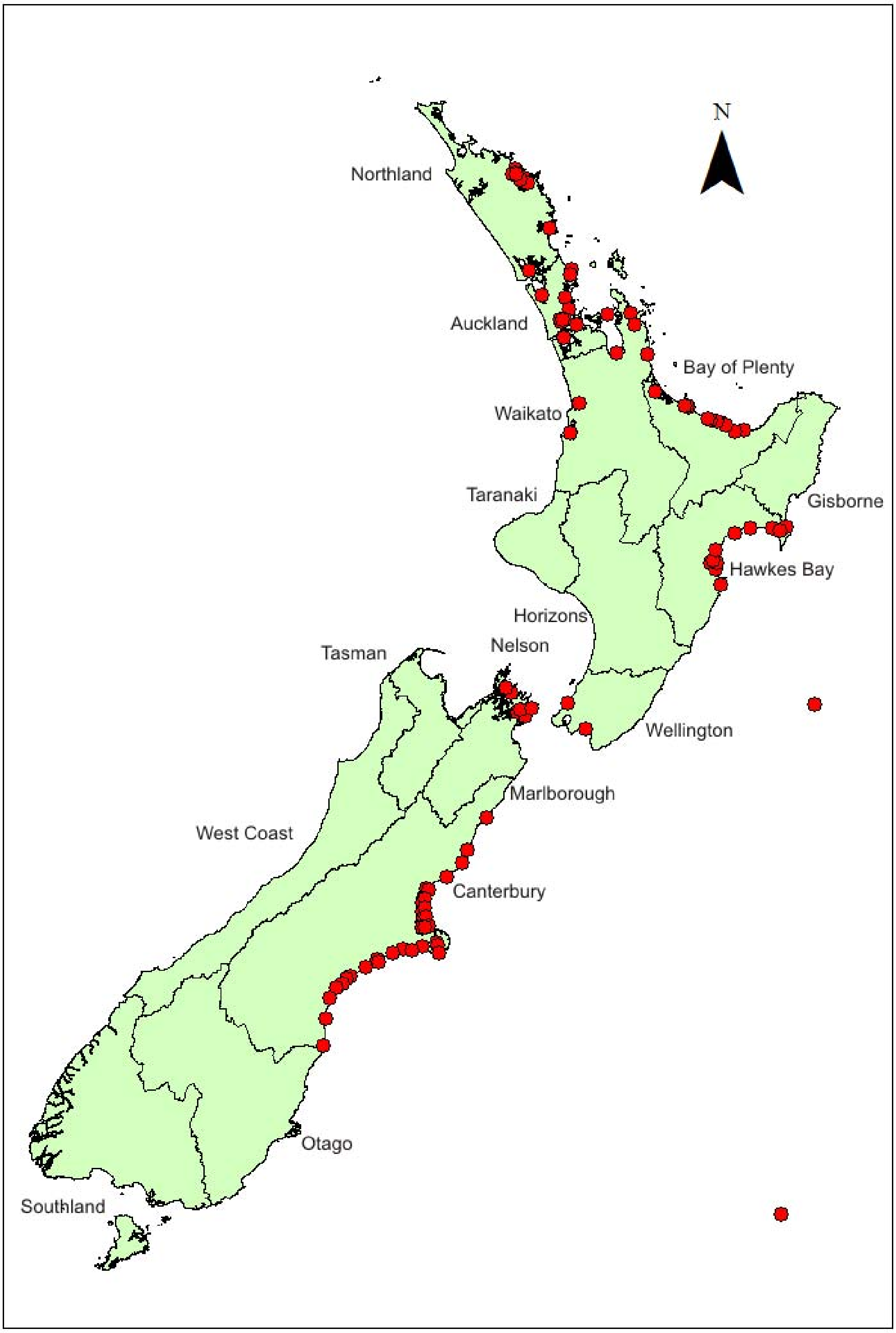

Figure 26: Location of current seawater oxygen monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

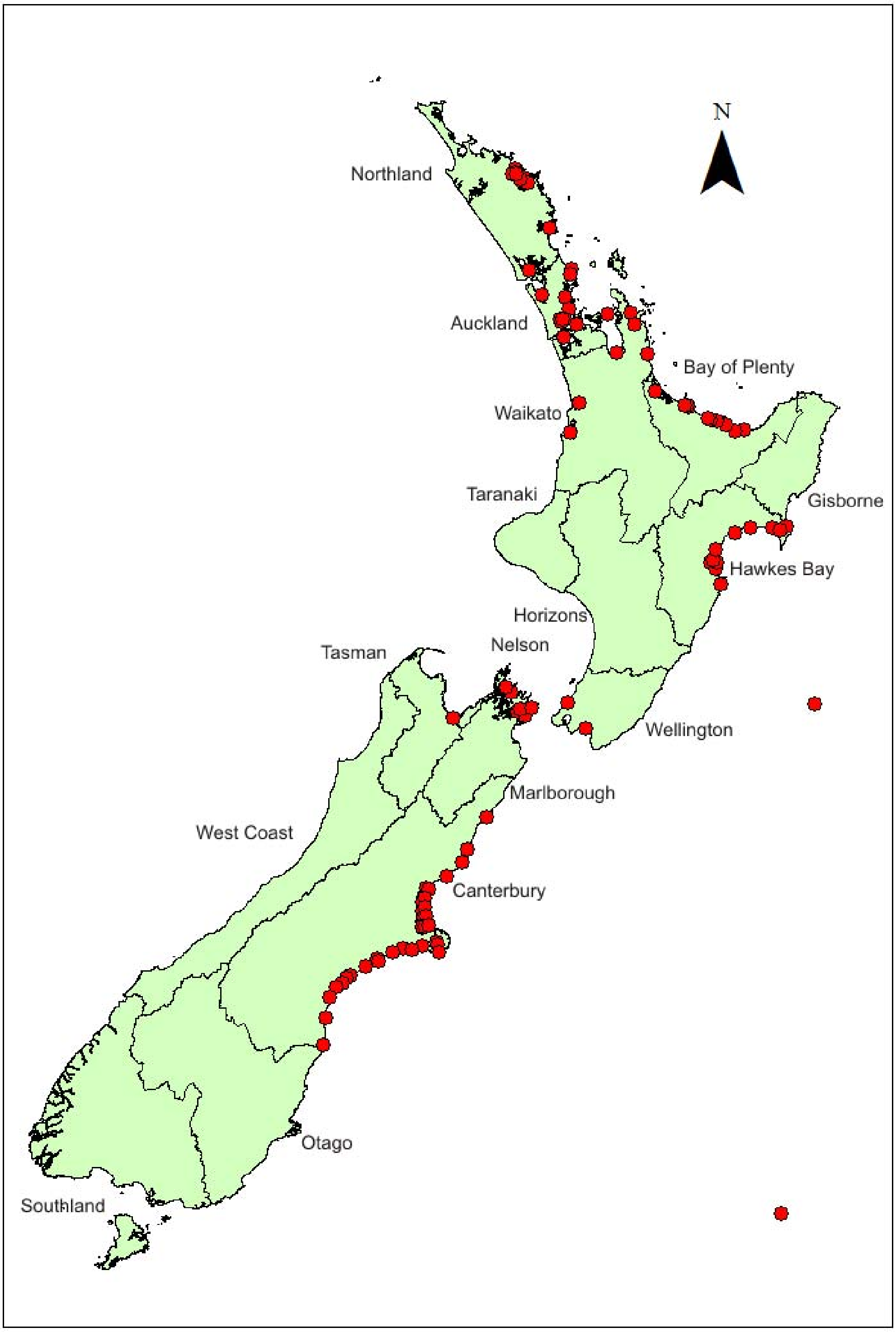

Figure 27: Location of current seawater nitrate (including nitrate + nitrite) monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Water clarity and suspended sediments: Water clarity, the inverse of which is turbidity, is a function of phytoplankton, suspended sediment and dissolved yellow substance concentrations. Suspended sediments are also called suspended solids, suspended particulates, or suspended particulate matter, and in New Zealand's estuarine and coastal waters are often the major source of turbidity.

Use. Water clarity is an important driver of primary productivity in surface and shallow waters. Measurement of suspended sediment concentrations can be used to specifically address NZCPS 22 requirements around controlling sedimentation. Suspended sediment is known to affect primary productivity (through its effect on water clarity) and the distribution and condition of macroalgae, seagrasses and invertebrate suspension feeders.

Responsiveness. Water clarity can change as a result of nutrient inputs (eutrophication), terrestrial sediment inputs, mining, dumping, dredging, fishing and wave- or current-driven erosion of the sea floor, or high water column primary production. Suspended sediment concentrations can change as a result of terrestrial sediment inputs, mining, dumping, dredging, fishing and wave- or current-driven erosion of the sea floor.

Variability. No analyses of water clarity and suspended sediment concentrations over time are known.

Degree of monitoring. Some measure of water clarity is made in most marine national monitoring programmes (coastal and offshore), especially where eutrophication is a problem. In New Zealand, a variety of methods are used on water samples, mainly taken from around the coast (Figure 28).

Methods. In freshwater systems, water clarity is measured using standard Secchi or black disk techniques. In marine waters the same methods are sometimes employed but turbidity is typically measured directly with various instruments (e.g., nephelometers, optical backscatter sensors, transmissometers) and expressed either as NTU (Nephelometric Turbidity Unit), FTU (Formazin Turbidity Unit) or converted by calibration into $mg.g^{-1}$. Occasionally, suspended solid concentrations as total or volatile (organic) and inorganic are measured. Coastally, suspended particulate matter in surface waters can now be assessed from satellite imaging of ocean colour using a variety of approaches (Pinkerton pers. comm.) although these have only been validated in some New Zealand regions (including Hauraki Gulf, South Taranaki Bight (Pinkerton et al. 2013a, b), and are not available on days when there is cloud cover (e.g., during many rainfall events). This approach is being utilised by some councils, while others use *in situ* infra-red backscatter devices that collect high resolution temporal data at a single point, or single time - single point water sampling. Variable use of all these different measures is likely to hinder comparison between regions in assessing effects related to sedimentation and sediment disturbance.

Utility in MEMP. Of these two variables suspended sediment is probably the more important, being specifically mentioned in the NZCPS (Table 5). However, natural variability is likely to be high both in space (and depth) and time, and magnitude and duration of events is likely to be the driver of ecological responses, making cost-effective measurement difficult. While research is underway to derive algorithms for remote assessment from satellite imagery, not only would these need to be validated across the territorial sea, but the ability of surface values in clear weather to be an adequate representation of state would need to determined before this could be a useful part of an MEMP.

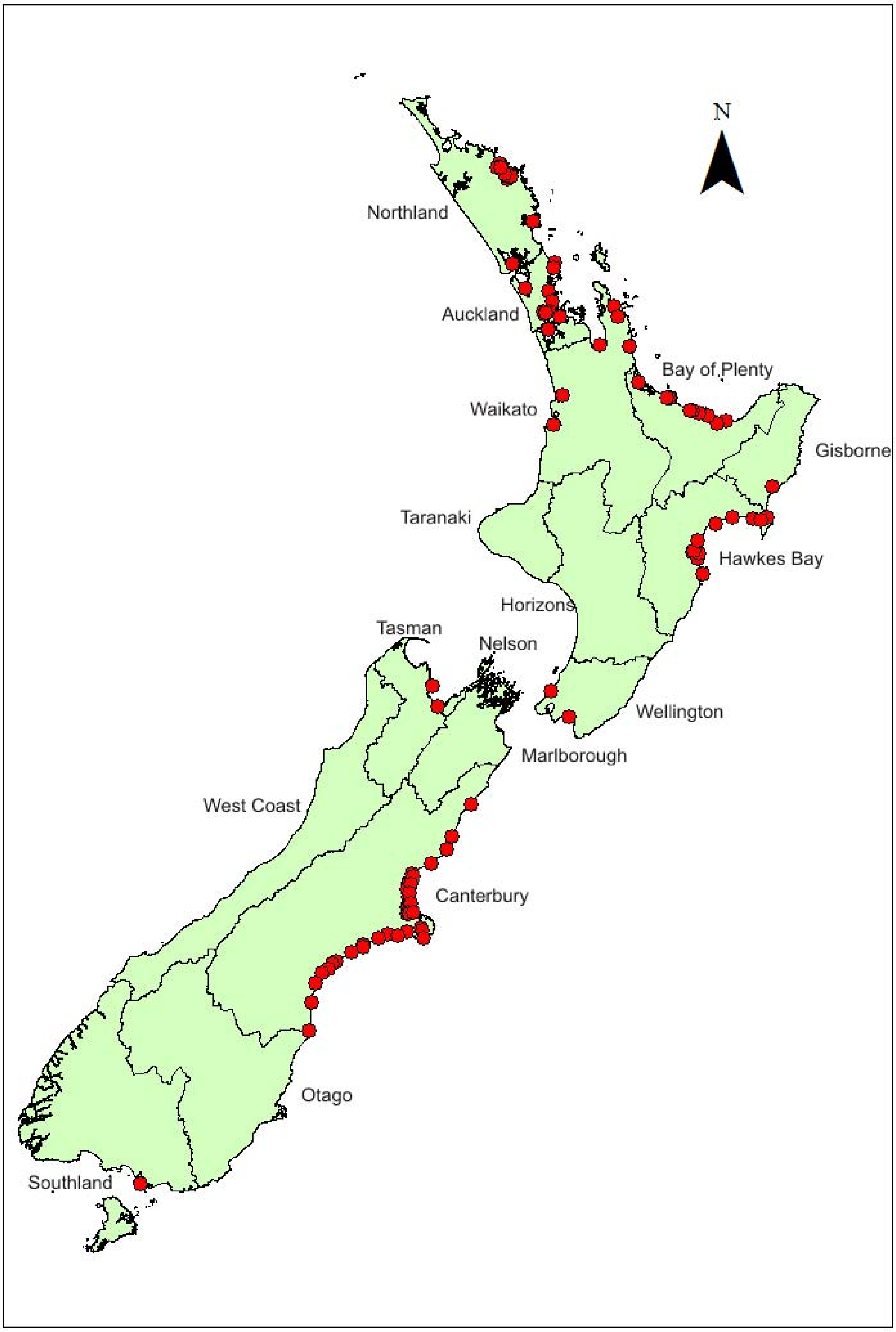

Figure 28: Location of current seawater clarity (including suspended sediment concentrations) monitoring sites in the meta-data catalogue (http://www.niwa.co.nz/coasts-and-oceans/projects/marine-environmental-monitoring-in-new-zealand).

Currents:

Use. Information on currents, whether it be extent, speed or depth, cannot be used as a surrogate for anything else, although the distribution of many species is related to current (amongst a range of other physical variables).

Responsiveness. Changes in currents are likely to accompany climate change, driven by both changes in sea level and movement of water masses.

Variation. Most information on variation in currents comes from models driven by different climatic conditions.

Degree of monitoring and Methods. Few countries' monitoring programmes measure small-scale coastal currents, focussing more on oceanic currents. Broader scale information is provided by the Global Drifter Program (GDP), with data available from the GDP Operations Center at http://www.aoml.noaa.gov/phod/dac/gdp_doc.php, although GDP drifters in the New Zealand region are relatively sparse. There are very few long-term current measurement sites in New Zealand, even around the ports, due to the expense of data collection, high maintenance requirements and the ability to successfully model currents. Various model grids exist from New Zealand-wide regional grids (20–100 km resolution) to local area models (300 m to 10 km grid resolution) covering open-coast bights down to estuaries. Coastally, these models need verification and there are a number of locations where currents could be measured that would increase modelling abilities (e.g., the east coast of the Coromandel Peninsula and the Bay of Plenty where currents are more driven by winds and the East Auckland Current than by tides). Such locations would benefit from short to moderate-term deployments and may not need long-term monitoring to be useful.

Utility in MEMP. This variable is a driver for some biological responses and is likely to show variation with climate change. However, as it is amenable to modelling, it should not be considered high priority for inclusion in an MEMP, beyond involvement in international programmes.

Wave height and frequency:

Use. Location-specific wave climates affect coastal erosion and flooding and can be used as a surrogate for this risk. The distribution of many species is also related to wave climate (amongst a range of other physical variables).

Responsiveness. Changes in wave conditions will occur as a result of climate change, directly associated with changing wind patterns and indirectly associated with sea level rise, which will expose progressively higher elevations to damaging wave action. Numerical models have been used to simulate wave conditions under two climate-change scenarios (R. Gorman NIWA pers. comm.). These studies suggest that sea level rise is likely to be the most important driver on changes in wave height and frequency, with direct changes in wave climate expected to be minor for most parts of the New Zealand coast (relative to more significant projected increases and decreases in wave energy elsewhere in the world).

Variability. A recently completed project has simulated 40 years of wave climate for the New Zealand region at approximately 10 km spatial resolution (and on a global scale at approximately 120 km resolution) (Gorman et al. 2010 and is available on Coastal Explorer (http://wrenz.niwa.co.nz/webmodel/coastal).

Degree of monitoring and Methods. Wave data from the nearshore area are collected using consistent techniques in some regions of the country, especially by port authorities, though in too few locations to fully characterise wave climate for all parts of the New Zealand coast. This can instead be done by using numerical wave models, validated by the available in situ records, as well as by satellite altimeter measurements. A recent validation study demonstrates that New Zealand models provide accurate wave statistics for the open coast, but further work is required in sheltered waters.

Utility in MEMP. This variable is a driver for some biological responses and a surrogate for risk of coastal erosion and flooding. The data can be collected both remotely and at long-term coastal sites. While the variable is of prime importance for determining the degree of coastal risk, for both humans and estuarine and coastal ecological systems, associated with climate change, it can be successfully modelled so would not need to be included in an MEMP.

4.5 Stratification considerations for national reporting

Statistics generated to report on what is happening at the national level ideally need to incorporate data from a broad spatial coverage or, as a minimum, from representative point locations. National level reporting generally also needs to be able to report/compare what is happening within and between different regions, which again relies on spatial stratification. However, spatial stratification alone is not sufficient as purely spatial stratification can be confounded by the spatial distributions of specific habitats/environments. Finally, in many countries national statistics report on environmental changes relative to the degree of stress that the environment is under. Thus, the monitoring design developed within this project considers spatial coverage, physical environments and stressors.

Spatial coverage: location and distribution:
Spatial coverage of a variable needs to include data from north to south, both to the east and west of the North and South Islands if it is to be reported on nationally. There is no one stratification scheme that can be recommended for use. For example, the coastal oceanographic regions utilised for stratification of the sea level gauges (Figure 21) are not accepted by oceanographers for extension into the oceanic area. Biogeographic regions differ between coastal and ocean regions and are frequently species-specific (e.g., Shears et al. (2008) for subtidal rocky reefs, Nelson (1994) for macroalgae, Francis (1996) for fish, Jones et al. (2008) for seagrass). For the coast, the bioregions used by the Department of Conservation (Ministry of Fisheries & Department of Conservation 2008) and MPI (http://www.marinebiosecurity.org.nz/project-map-port/), as they are mostly the same (Figure 29).

Environments:
Environments can be considered based on a number of different definitions or classification schemes. For the oceanic environment, a number of physical classification schemes are available: Marine Environment Classification (MEC: Snelder et al. 2004, Snelder et al. 2006, Figure 30), Benthic-optimised Marine Environment Classification (BOMEC: Leathwick et al. 2009)) and the demersal fish community classification (Leathwick et al. 2006b). None of these is considered appropriate for the nearshore waters as they have a demonstrated lack of ability to differentiate different areas within the nearshore.

For coastal waters, the variables identification working group considered that separation based on water depth (intertidal, shallow subtidal, subtidal 15–50m), exposure (estuaries, beaches/open coast) and substrate type (rocky, soft-sediment), similar to that used by MacDiarmid (2012a) would be appropriate. New Zealand estuaries have been classified based on their geomorphology (Hume & Herdendorf 1988, http://wrenz.niwa.co.nz/webmodel/coastal). Presently, a classification system focused on retention of sediments and nutrients is being developed (DOC, University of Canterbury, NIWA) in order to better assess threats of nutrient inputs and sediment deposition (the Estuarine Trophic Index). However, it is important to note that this system will not be able to assess threats associated with decreases in water clarity and suspended sediments and classification based on neither water retention nor geomorphology have proven to be useful for reporting on estuarine impacts related to sediment contaminant, mud, organic or chlorophyll-a content.

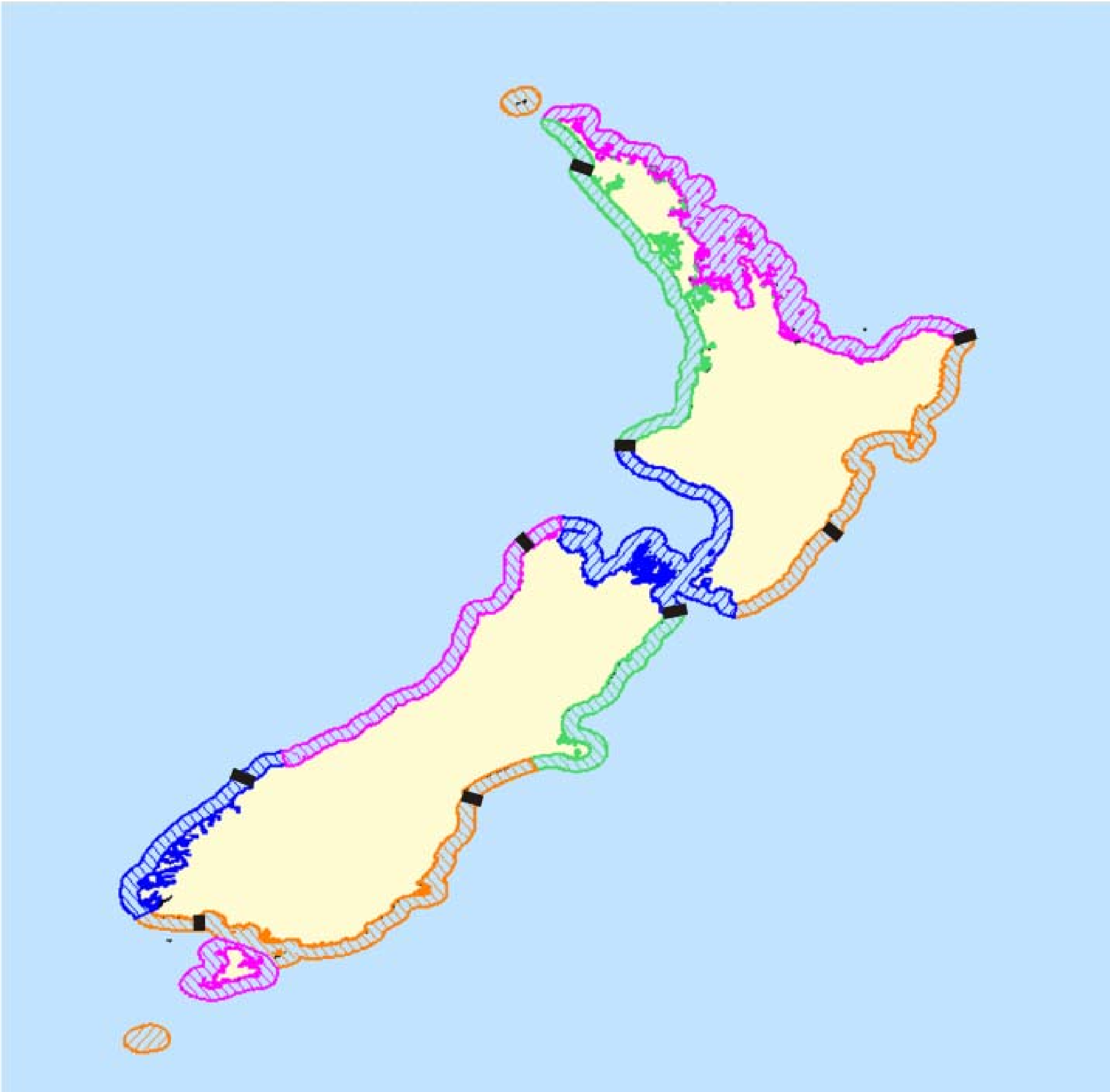

Figure 29: Department of Conservation coastal bioregions (thick black lines) overlain on MPI biosecurity bioregions (colour shades) taken from http://www.marinebiosecurity.org.nz/project-map-port/.

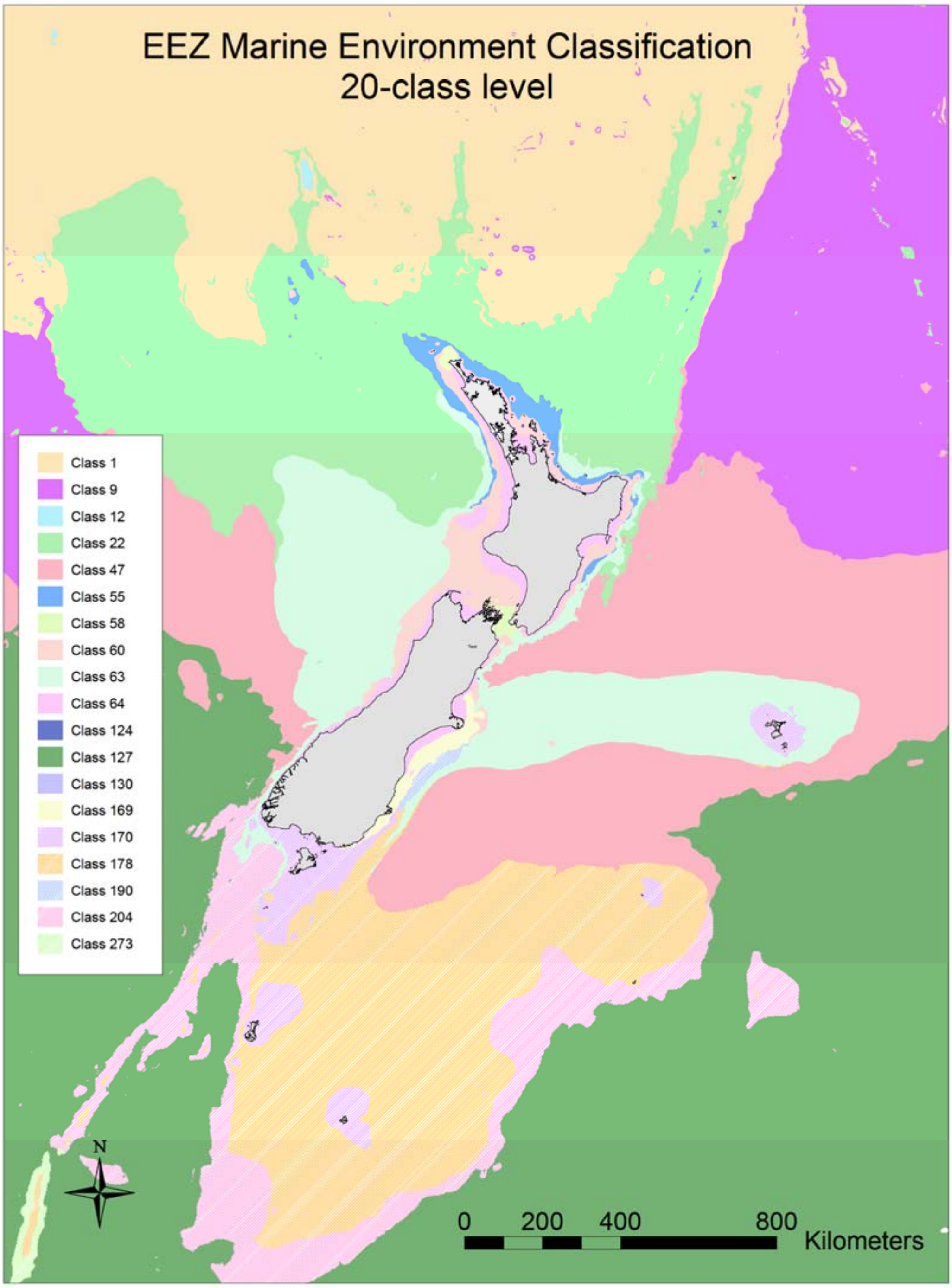

Figure 30: Classification of the marine environment based on the MEC at a 20 class resolution.

Stressors:
Stratification by all stressors, or even just the top ten identified by MacDiarmid et al. (2012a) in any monitoring design would obviously be cost prohibitive, even if spatially explicit information on the magnitude of all these stressors was available. While geographic information on some stressors is available (Table 6), there are many stressors for which complete geographic information is unavailable.

Table 6: Present and future sources of geographic information on specific stressors which could be used to guide reporting. Blank space indicates present lack of a source.

Stressor	Present	Future
Acidification	Climate change atlas for oceanic areas (Boyd & Law 2011)	
Climate change	Climate change atlas for oceanic areas (Boyd & Law 2011)	Areas of change from SST analysis Sea level, wave and current predicted changes from models for inshore areas
Fishing	Fishing footprint (Baird et al. 2011)	
River inputs: sediment loading and turbidity	Spatially explicit sediment yields (Hicks et al. 2011)	Areas defined by analysis of remotely assessed SPM
Invasive species	Major ports and shipping transit areas	
Dumping of dredged sediment		Consent information
Algal blooms - both toxic and massive		
Reclamation		
Pollution from urban sources	Major population areas	
Aquaculture		Consent information

Moreover, many areas would have multiple stressors operating on them and multiple stressors can interact in many ways: additively (Halpern et al. 2007), antagonistically (the effect of two multiple stressors are less than either separately (Thrush et al. 2008)) or synergistically (the effect of two is greater than their sum (Thrush et al. 2008)). There is insufficient knowledge about most stressors and their likely impacts on the marine environment to determine how they might interact. Even reducing the stressors to those that can be managed within New Zealand (e.g., fishing, human activities in catchments, marine engineering projects, mining and aquaculture), would still mean that a strictly stressor-stratification approach to monitoring cannot reasonably be taken for any but a few remotely assessed variables. Reporting potential effects of stressors on other variables can occur in the analysis and interpretation of changes, rather than in the design of sampling. Lack of a strict stressor stratification in the design of monitoring is also a coping strategy (future proofing) as stressors frequently change in importance and location. For example, emerging contaminants, increased likelihood of off-shore mining and the increased prevalence of intensive dairy farming.

5 RECOMMENDED MARINE ENVIRONMENTAL MONITORING PROGRAMME BASED ON CURRENTLY COLLECTED DATA

Table 7 summarises the variables discussed in Sections 4.1 to 4.3 sorted by the national coverage of present data collection. The eight variables discussed in this section are presently collected (even if not analysed) at least five yearly and have broad national coverage (i.e., monitored at locations across the east to west and north to south of New Zealand's marine environment). In all cases, standard methods are used, although for some there is more than one standard method. Their usefulness for reporting and their known responsiveness to stressors is, however, variable.

Table 7: A summary of variables discussed in Sections 4.1 to 4.3, mainly in terms of their present national coverage, although other aspects of their utility to a MEMP are given. Sum is the sum of both usage and response to pressures. Coverage, variability and method scores are defined at end of Section 4.1. High scores are good, low scores are not. Water column ammonium, nitrate, oxygen, pH, pCO_2 and DIC have been aggregated.

	Coverage	Sum	Variability	Methods
max score	*5*	*6*	*1*	*2*
Sea surface water temperature	5	2	1	1
Sea surface Chlorophyll-a	4	5	1	1
Sea surface suspended particulate matter	4	5	-1	1
Sea level	3 to 5	3	1	2
Soft-sediment macroinvertebrate communities:	3	6	1	2
Sediment grainsize	3	6	-1	1
Demersal fish communities	3	3	0	1
Non-indigenous species	3	1	-1	2
Sediment metal concentrations	2	5	1	1
Sediment organic content	2	2	1	1
Sediment nitrogen content	2	2	-1	1
Sediment chlorophyll-a	1	3	1	2
Water chemistry	1	4	-1	0–2
Zooplankton and phytoplankton	1	4	-1	1
Wave height and frequency	1	3	1	1
Currents		2	1	1
Soft sediment epibiotic communities		5	1	-1
Reef macroalgae, macrofauna and fish	1	4	1	-1
Sedimentation rates		4	-1	-1
The number of species in the threatened, at risk, or protected categories	1	2	-1	-1
Erosion of coastal areas	1	2	-1	-1
Biogenic habitats	1	6	-1	-2
Sedimentary habitats		5	1	-2
Key species	0	2	-1	-2

5.1 Sea surface physical and chemical variables.

The following variables include two that are important for assessing climate change occurrence and implications (temperature, sea level rise), an important indicator of sediment in the coastal zone (sea-surface particulate matter), and a surrogate for ocean productivity (sea-surface chlorophyll-a). The following format is used:

(1) information about the current monitoring and the questions it could be used to answer;

(2) appropriate reporting scales (in time and space);

(3) analyses that would be useful for national reporting; and

(4) any problems that need to be solved or extensions that would increase the robustness of reporting (see Table 8).

5.1.1 Sea surface temperature across the Territorial Sea and the EEZ

1. Sea surface temperature data are available from satellite imagery at fine spatial resolutions (1 – 4 km) daily, dependent on cloud cover. Temperature is a critical environmental variable affecting species metabolic rates and distributions and net primary production and is hence an important variable to monitor both to observe and to predict climate-related change to the marine environment.

2. These data are usually composited in time, as daily information usually has missing information because of clouds. As the time period of aggregation increases to 8 days and finally 1 month, the spatial coverage increases but the probability of averaging over important spatial and temporal variation also increases. At present, any analyses of trends over time are most frequently based on monthly composites. Rather than using oceanic geographic regions as spatial units for reporting, EOF (empirical orthogonal functional analysis, e.g., Palacios-Hernández et al. 2010) is used to categorise the data into spatial subsets in terms of the amount of variation they explain. Seasonality can be removed and trends and long-term temporal patterns identified.

3. In future it may be profitable not just to report on spatial areas defined by variation, but also on areas where large climate change is predicted to occur (e.g., based on the climate change atlas (Boyd & Law 2011) or as further developed by NIWA project CCII133).

4. While data are presently collected, it is not usually analysed. An analytical and reporting framework would need to be developed.

5.1.2 Sea level height

1. Sea-surface height is measured every 10 days at any particular track position, as the satellite passes over New Zealand, again dependent on cloud cover. However, close to the coast, sea level gauge readings are essential because interference from the land can compromise readings, and to avoid differences driven by tectonic movements. Most coastal regions (8 out of 10) have at least one sea level gauge where readings are collected by data-loggers. Sea-level rise is expected to affect coastal erosion, flooding (river and storm-tide), tide range, estuary tidal volumes, salinization of lowland streams and groundwater aquifers and species distributions and to be an indicator that integrates the overall rate of climate change globally and regionally. Longer-term sea level gauge records are needed to move from IPCC global projections to regional and subregional projections that allow planning by councils.

2. Offshore, sea-level height is generally analysed approximately 6-monthly when processed altimeter data become available. Average, trend and the standard deviation will be reported for a regional box around New Zealand on a NIWA webpage in the near future. SSH offshore measurements have proven to be reasonably well correlated to nearshore measurements, with some variation driven by offshore oceanic currents and upwelling/downwelling activities at the local/regional scale. Reporting of coastal sea-level is generally done on an oceanographic sub-region (Figure 21) (with only one gauge in most sub-regions) on an *ad hoc* basis, either on demand or for the Natural Hazards Annual Review:
http://www.naturalhazards.org.nz/NHRP/Publications/Natural-Hazards-Annual-Report.

3. Analysis also needs to be done to determine to what extent the longer term records at one site relate to the short-term records of other sites in the same sub-region.

4. At present, there is no viable open-coast gauge on the West Coast of South Island nor the South Taranaki Bight.

5.1.3 Sea surface particulate matter in the coastal zone.

1. Suspended particulate matter in surface waters of the coastal zone of New Zealand can now be estimated from satellite imaging of ocean colour at approximately 500 m resolution. The accuracy of the estimated concentration may vary with region (e.g., Pinkerton et al. 2013b). This measure can be calculated daily, dependent on cloud cover and could be used to specifically address NZCPS 22 requirements on controls of sedimentation.

2. This variable would best be composited in time as for sea surface temperature, i.e., monthly composites, using EOF-derived spatial units.

3. Future reporting related to regional and unitary council boundaries would also be useful.

4. This is recently developed methodology requiring validation in many areas of New Zealand to fully separate the colour associated with particulates from dissolved matter and chlorophyll. An analytical and reporting framework would also need to be developed.

5.1.4 Sea surface chlorophyll-a across the EEZ (excluding nearshore waters)

1. Sea surface chlorophyll-a data are available for the EEZ at fine spatial resolutions (500 m – 4 km), from ocean colour satellite sensors. These data is available daily, dependent on cloud cover; but as yet chlorophyll-a from ocean colour data has not been validated over the whole New Zealand coastal zone. Sea surface chlorophyll-a in the ocean is a surrogate for productivity and changes can be used to indicate increasing eutrophication as it integrates nutrient availability, oceanography and biological factors.

2. Derived from ocean colour products, these data are usually composited in time and space as for sea surface temperature, i.e., monthly composites and EOF-derived spatial units.

3. Rather than simply reporting on chlorophyll-a, this variable can be used together with other information to estimate phytoplankton biomass and net primary productivity (NPP), which is the major source of energy in oceanic ecosystems. Technology and algorithms have been developed to estimate these variables because of their high spatial and temporal variability. However, estimates are algorithm dependent (a factor of more than 2 between all the various methods of estimating NPP (Campbell et al. 2002)) and none of the methods has been adequately validated in New Zealand waters (Schwarz et al. 2008).

4. While colour data are presently collected, it is not usually post- processed at all. An analytical and reporting framework would need to be developed.

Table 8: Proposed national-scale monitoring based on present sampling.

Variables	Analysed as	Represent	Requires
Sea surface temperature across the EEZ	Changes over time	Change in temperature, oceanographic stratification, ocean currents, IPO, SOI	Analysis
Sea level height/rise	Changes over time	Change in sea level, waves	Two additional coastal locations
Sea surface particulate matter in nearshore waters	Changes over time, relationship with freshwater inflows and increased storminess	Change in sediment inputs, turbidity	Validation of algorithms for NZ nearshore waters
Sea surface chlorophyll a (and associated ocean colour-derived products)	Changes over time	Change in productivity, oceanographic stratification, ocean currents	Validation of algorithms for NZ nearshore waters
Demersal fish less than 1200m deep	Changes over time, relationship with fishing intensity and stratification, potentially variation with temperature and productivity	Effect of fishing, changes in fish diversity, changes in size composition, changes in trophic state, changes in key species	At least 3 new locations from the northeast and the west of North Island
Estuarine intertidal soft-sediment grain-size, nutrients, chlorophyll a, organic content, heavy metals and macrofauna	Changes over time, relationship with contamination, sedimentation, turbidity, sea level rise, sea temperature, currents, storminess, effects of soft-sediment non-indigenous species, possibly freshwater inflow	Changes in macroinvertebrate biodiversity, estuarine health, key species, non-indigenous species, contamination, nutrients, sediment grainsize, organic content and primary productivity	At least 2 locations on West Coast of South Island, Increased frequency in some locations
Non-indigenous species (presence and abundance) from harbours	Changes over time, relationship with contamination, sedimentation, turbidity, productivity, sea level rise, sea temperature, natural biodiversity	Changes in spatial extent, range extent, and number of new introductions	

5.2 Ecological variables

None of the variables discussed in Section 5.1 allow assessment of changes in biodiversity, ecological integrity or in most ecosystem goods and services. Assessments of biodiversity or ecological integrity require information on taxa/species and ecological community distribution, abundance and condition (among other things). The following variables (see Table 8 for a summary) allow a better assessment of such factors, based on two ecosystem components (fish and macroinvertebrates) and estimates of non-indigenous species. These are currently available from either our estuaries (including harbours), or some inshore and mid-depth ocean areas. Both of the ecosystem components suggested are important and rich subsets of the total ecosystem. Estimates of biodiversity (e.g., number of species per square metre) made from these components, unlike the national scale measures suggested for the Marine Biodiversity Tier 1 statistics (Lundquist et al. in review), can be used to determine declines in biodiversity over time.

The following format is used in this section: (1) information about the current monitoring and the questions it could be used to answer; (2) appropriate reporting scales (in time and space); (3) analyses that would be useful for national reporting; and (4) any problems that need to be solved or extensions that would increase the robustness of reporting.

5.2.1 Demersal fish communities.

1. Data on relative demersal fish abundance are collected at least three yearly from eight areas around New Zealand: mid-depth ranges of the Chatham Rise Southland and Sub-Antarctic; inshore areas of the East coast and West coast South Island; and the areas of the four main scampi fisheries. Despite a lack of consistent trawl and mesh size between reporting areas, data from the trawl survey database can be analysed to give overall demersal fish biodiversity and size structure within an area, the condition of some fisheries and some information on individual species abundances, and biomass and trophic links (Tuck et al. 2009). Data on demersal fish abundance can also contribute to measures of ecosystem integrity and to economic and cultural aspects of ecosystem goods and services. Moreover some of the species are important recreationally and culturally (e.g., snapper, blue cod, groper) and would probably be chosen to be “key” species if a New Zealand list of these were compiled. However, the data cannot be used as a surrogate for other parts of the ecosystem and there is little information on responses of fish communities to most stressors, either individually or in conjunction.

2. The sampling strategy with respect to locations, stratification (with respect to depth and fishing intensity and type), replication and resolution follows a random sampling design stratified for depth zones and spatial coverage, and has been optimised to minimise the coefficient of variation of target species of the survey, within each area. Thus reporting is best based on each area separately. As data is collected at least three yearly, a three or six yearly reporting cycle would be optimum.

3. Information on the stressor presently considered to be key (trawl footprint data e.g., DAE2010-04) is collected and available so future reporting could both report on status and analyse for changes specifically related to bottom fishing pressure. Furthermore, these analyses could be combined with the analysis of sea-surface variables to determine the effects of any changes in temperature, productivity and (in near-shore areas) surface particulate matter (e.g., as suggested by McClatchie et al. 1997 and planned project DEE2014/01; hypotheses to explain changes in catchability in the Sub-Antarctic trawl survey for hoki and other fish species). Importantly, recreationally and culturally valuable species are often the focus of monitoring in marine reserves and amalgamating data on these species from the demersal trawl collections and the marine reserve monitoring would be fruitful to extend spatial coverage. However,

amalgamation could be done only at time of reporting as the monitoring methods are quite different (e.g., trawling, which would be inappropriate in a marine reserve, compared with diver counts or baited video). This could be done utilising meta-analysis techniques investigating whether changes are similar in terms of direction and magnitude between areas for both data derived from monitoring reserves and the trawl survey data.

4. There are some problems with the present sampling that would need to be overcome in order for demersal fish monitoring to form part of a robust national monitoring and reporting strategy. Firstly, lack of present sampling in some areas, e.g., Hauraki Gulf and east coast North Island (where sampling has previously been conducted) and the west coast of the North Island. Secondly gear type differs among areas and depths (although is generally consistent within a survey series), so that differences between areas in species richness, size structure and types of species could merely be due to differences in gear type. While changes over time within each survey area would not suffer from this problem, changes over time that do not occur in all areas would have to be carefully considered in case they are generated by different species or size classes responding differently to stressors. This caveat would also apply to any meta-analysis combining data from monitoring reserves and the trawl survey data.

5.2.2 Macroinvertebrate communities and sediment characteristics of estuaries and harbours.

1. Soft-sediment macroinvertebrate community data are collected from intertidal areas of 63 of the 441 New Zealand estuaries (as defined by the Estuarine Classification database). Data are collected using a standard methodology with sampling occurring at a frequency ranging from bimonthly to five yearly depending on the estuary/harbour. Ecosystem goods and services provided by such communities cover benefits from food production and recreational opportunities to contaminant processing and cultural benefits and extend beyond the immediate area into the adjacent coast (Thrush et al. 2014, Townsend et al. 2011). The community data can be used to calculate biodiversity and also contributes to measures of ecosystem integrity and to most aspects of ecosystem goods and services. Internationally and nationally such data are used as a surrogate for health of the ecosystem, thus this data can be used to answer questions about changes over time in the biodiversity and health of our estuaries, as well as changes in specific goods and services and changing species distributions associated with climate change. Moreover, all of the locations have data on sediment grainsize and most (60) have data on sediment concentrations of copper, lead and zinc collected. A smaller number of locations have data on sediment concentrations of chlorophyll-a, organic content and nitrogen collected (24, 35 and 40 respectively). These sediment characteristics cover stressors (mud, nitrogen, copper, lead, zinc and cadmium), and a surrogate for primary productivity (chlorophyll-a), thus strengthening the ability of reporting to associate change with specific pressures. Recent work on mapping of ecosystem goods and services (Townsend et al. 2011) offers a way in which the sediment and macroinvertebrate data could be combined with broad-scale information on depth, currents, waves, sea surface temperature and sea surface chlorophyll-a data to estimate changes in goods and services.

2. Sampling frequency varies from two monthly to five yearly, thus five yearly reporting would be most appropriate Spatial reporting can either be done on a site-by-site basis, summarised up to the estuary scale, or stratified by stressors. Stratification by estuary type has not proven to be useful in past analyses of central to northern estuaries (Thrush et al. 2003, de Juan et al. 2013).

3. A fruitful approach for reporting on the present information could be to broaden the Benthic Health Model approach developed and utilised by Auckland Council (Anderson et al. 2006, Hewitt et al. 2009), which relates changes in health to stormwater contamination and sediment mud content, to include other regions and stress gradients (Hewitt et al. 2005). Continued development of some type of functional index (Lohrer & Rodil 2011) (in line with the concept

of ecosystem integrity) would also be a useful reporting tool as again this would not be affected by differences in species composition throughout the country. Both these indices (health and function), integrated with information on stressors, allow changes over time to be assessed in a cause and effect framework. Reporting should be widened to include results of analyses of the sea-surface measurements (Section 5.2) to determine whether related changes are occurring.

4. There are some problems with the present sampling. Firstly, lack of sampling in the west coast of the North Island (at least two estuaries need sampling here, based either on regional council boundaries or coastal bioregions). Secondly, standardising the sedimentary analyses so that all sites are sampled for metals, nitrogen, organic content and chlorophyll-a concentrations. Thirdly, standardising the taxonomic resolution of the macroinvertebrate identifications. Finally, at present, sampling frequency varies from two monthly to five yearly. This does not preclude robust monitoring if the programme has been designed as a spatially and temporally nested programme and at least some sites are continuously monitored (Hewitt & Thrush 2007). Without some continuously monitored sites, temporal cycles related to ENSO may result in detection of changes that are the result of natural cycles. In the case of a national monitoring strategy, continuously monitored sites need to be spatially distributed around the country and at present continuous monitoring of some sites only occurs in the northern half of the North Island.

5.2.3 Non-indigenous species.

1. While non-indigenous species are monitored mainly to detect incursions by unwanted organisms, knowledge of the abundance and spread of non-indigenous species is usually considered to be an indicator of ecosystem integrity. The number of non-indigenous species is presently suggested to be part of the Tier 1 Biodiversity Statistic (Lundquist et al. in review).

2. The Marine High Risk Site Surveillance (MHRSS) programme collects data every six months in 11 harbours that have ports and marinas of first entry for international vessels (Figure 5). Collection methodology was optimised by literature review, expert survey and peer review and analysis of data held by international collaborators on high profile marine pests (Inglis et al. 2006a). Optimisation of sample design, including sample effort, was undertaken using predictive distribution mapping and dispersion modeling (Inglis et al. 2006a, b, 2011), estimates of method sensitivity (e.g., Hayes et al. 2005) and risk-based modelling using stochastic scenario trees (Morrisey et al. 2012b). A summary of the design considerations for the MHRSS is provided in Morrisey et al. (2012a). Additional data on non-indigenous species detected in New Zealand are reported through the Marine Invasives Taxonomic Service, which manages identification and diagnostic services for the Ministry for Primary Industries' marine surveillance activities.

3. Useful national reporting would include: total numbers of both non-indigenous and cryptogenic species present in New Zealand; the number (and identity) of new-to-New Zealand species; and the number and identity of range extensions made by high profile non-indigenous species. Changes in the prevalence (#observations/sample effort) of high profile non-indigenous species in the 11 harbours surveyed by the MHRSS would also be useful. Some of these are presently reported on, e.g., an annual report on detections of new-to-NZ species, and range extensions of established high-risk species is provided each year to MPI as part of the service requirements of the MHRSS and MITS.

4. The robustness of this reporting would be improved by extending data collections and reporting to locations outside the 11 harbours surveyed by the MHRSS.

6 GAPS

This section focuses on the extension of monitoring presently carried out around New Zealand, that would be required to allow robust reporting of important variables that are either currently monitored in very few places or that do not have consistent methods used. The order of the section suggests the relative importance to national reporting considered by the authors to be a reflection of the Environment Domain Plan and the NRS draft marine strategy.

6.1 Water chemistry

Presently water chemistry (oxygen, pH, pCO_2, chlorophyll-a, nitrate, dissolved inorganic carbon and ammonia) monitoring does not occur in as many estuaries or harbours as macroinvertebrate and sediment characteristics monitoring. This is because measurements of benthic, rather than water column, variables are more likely to be important in estuarine and harbour areas, as estuarine sediments generally serve as sinks for inputs of sediments and contaminants. However, carbonates and nutrients are likely to be of increasing concern in the future. Water chemistry monitoring would be able to answer questions related to whether New Zealand coastal waters were becoming eutrophic, oxygen concentrations were becoming lower and whether coastal and ocean acidity was increasing. If acidification was detected, the relative roles of broad-scale change versus local (terrestrially derived) inputs would be able to be determined.

Data on water chemistry are collected, mainly by regional council, from 34 – 52 estuaries and 43 – 48 coastal locations, depending on the variable, using standard, quality assured methods. These sample locations do not provide a good national coverage, with the south and west coast of the South Island not sampled at all (with the exception of chlorophyll-a in Fiordland) and most sampling on the west coast of the North Island being located in estuaries. Many of the regional councils, in conjunction with Cawthron, are presently considering setting up coastal mooring buoys and if possible these will be located off presently monitored rivers/estuaries. Another possible source of data are from aquaculture companies, if a standard methodology and sets of variables could be developed and accepted.

Importantly, there is currently only one long term (15-year long) time series of carbonate parameters (such as are used to assess ocean acidification) in the New Zealand region (the oceanic Munida time series off the Otago coast). While more such measures are needed for oceanic regions, they are particularly needed in nearshore coastal regions (including estuaries where many of New Zealand's shellfisheries are located). Information on natural variability in coastal seawater chemistry is required to help in the interpretation of apparent ocean acidification impacts and management of these impacts; this is particularly important in light of other local factors that will influence organism responses (e.g., fishing, hypoxia, agricultural runoff, sedimentation), and also the actual values of pCO_2. Initial work is underway to develop a coastal ocean acidification monitoring network, including identification of sites, sampling and quality control logistics and development of a centralised analytical facility. This monitoring network will be in line with current efforts to develop an international ocean acidification monitoring network Global Ocean Acidification Observing Network: GOA-ON, in which New Zealand is playing an active role (through Dr Kim Currie). The network would utilise sites presently monitored, particularly those with coastal moorings, and extend to new sites, and measure those parameters presently recommended by GOA-ON (temperature, salinity, pressure, oxygen, carbon-system constraint (two of alkalinity, DIC, pH, pCO_2), fluorescence and irradiance, although nutrients are also likely to be included. Two steps towards this network are presently being undertaken: (1) autonomous pH sensors are currently being tested and (2) water sampling that will be used to determine an appropriate temporal frequency is being initiated.

Location of offshore instrument mooring is most likely to be driven by the considerations of an international network, and discussion with the Australian IMOS programme have been ongoing for a few years. Unfortunately, purchase and maintenance of such moorings is costly, e.g., NIWA has recently pulled their two deep sea moorings out while temporal analysis of their data are being conducted and IMOS is also struggling to find sufficient funding, so is unlikely to extend their sampling in the immediate future. In the current economic climate, enhancing measurement capabilities on ships of opportunity should be considered. Such measures could include near-surface salinity, pCO_2, dissolved oxygen, phytoplankton and zooplankton. An initial step would be to analyse repeat ship tracks to determine which ships would give time repeatable data in areas of specific interest (e.g., those predicted to change most according to New Zealand's Climate Change Atlas (Boyd & Law 2011), or those identified as notable in analyses of remotely sensed chlorophyll-a, temperature or surface water particulate matter data).

6.2 Water column biology

At present there is very little water column sampling of zooplankton and phytoplankton on which to base any robust reporting. Only one CPR transect is presently sampled in New Zealand, a long transect running down into Antarctic waters, important both nationally and internationally. Probably the most effective strategy for the future is to augment this by coupling it with water chemistry sampling by ships of opportunity.

For fish, there are two potential avenues of data. Firstly, MPI collates a Catch per unit effort (CPUE) time series, which does provide an index of biomass. Secondly, back scatter from acoustics has been validated as an index of mesopelagic biomass (O'Driscoll et al. 2011).

6.3 Habitats

Many national monitoring programmes are based on a hierarchical series of scales: (1) simultaneous and spatially continuous sampling of the entire area (e.g., using satellite imagery); (2) discrete sampling of broad areas within sub-areas (transect sampling by, for example, aerial photography, towed acoustic devices or towed sampling devices); (3) sampling of sentinel sites within the discrete sampling of the sub-areas (point sampling by, for example, coring or moored devices). Practicalities based on cost of sampling generally mean that the second level is not repeated frequently (e.g., once in multiple years) while the third level will be sampled more frequently. The monitoring design described in Section 5 has aspects of the first (satellite remote assessment) and third scale (point sampling) but not the second. For example, to be a fully hierarchical design, the intertidal estuarine and harbour monitoring sites in the meta-data catalogue would need to be nested within broader-scale monitoring of sedimentary or biogenic intertidal habitats.

Monitoring based on broad-scale seafloor mapping of both sediment characteristics, geology and benthic communities, across a range of depths, would be directly relevant to reporting on changes to ecosystem goods and services or ecological integrity. Unfortunately, to date, there are no cost-effective methods for doing this, although some intertidal broad-scale mapping is undertaken as was proposed by Robertson et al. (2002) and aerial photography of fringing vegetation is undertaken by some regional councils and unitary authorities. However, definitions of what to map, for example including a wider range of biogenic habitats (see Needham et al. 2013), and how to map cost effectively need to be agreed. DOC is presently reviewing their monitoring with the intention of bringing consistency across marine reserves and focusing on ecological integrity, which includes a focus on biogenic habitats (both soft and hard) that can be observed by video. Such monitoring offers the possibility to merge programmes in nearshore and EEZ waters by developing a standard methodology based on video and remote acoustic techniques. However, at present these techniques are still under development in NIWA's Coasts and Oceans Centre, DOC and MPI, frequently using data collected by Oceans Survey 2020 projects.

6.4 Nearshore biological communities

Increased monitoring in coastal areas would be fruitful. Such areas have their own set of stressors (e.g., fishing, mining) while still being affected, albeit usually at lower concentrations, by many land-based stressors. However, a lower intensity of a stressor does not necessarily mean a lesser impact. Species living in such areas are frequently more sensitive to land-based stressors than estuarine and harbour species and biodiversity is generally higher (Lohrer et al. 2006). Nearshore biological communities may also respond to increased temperature, wave events and acidification, as increased biodiversity increases the likelihood that there will be a species in the monitored community that will be living near the extreme of its environmental range (and thus its ability to cope with change).

There is some intertidal rocky reef time-series monitoring of macroflora and fauna, mainly in relatively pristine areas of the country and in some marine reserves, which could be used as a basis for a national monitoring programme. In particular, monitoring by the University of Canterbury has been conducted since 1993 at three locations across the South Island, in a programme set up specifically to measure temporal variability (Schiel 2011). It is consistent with international standards such as PISCO (Partnership for Interdisciplinary Studies of Coastal Oceans). These monitoring data could already be utilised for national reporting and, because the taxonomic resolution is the same across all sites, changes in biodiversity could be reported. Furthermore, a more extensive survey of over 100 sites (Schiel 2011) would be very useful in forming the basis of future long-term monitoring. Present time series analysis shows some concordance between sites in temporal patterns of some species (Schiel 2011) suggesting that it might be possible to use the existing long-term sites to fill in temporal gaps in monitoring for other sites (Hewitt & Thrush 2007).

Subtidally, DOC monitoring of reef macroalgae, macrofauna and fish, especially within marine reserves, could form the basis for national scale reporting once a regular time series extends over a reasonable number of years (more than 10 years, e.g., Wing & Jack 2010, Jack & Wing 2013, Wing & Jack 2013). Here also, there are a number of one- or two-off surveys that could be used as the start of a long-term monitoring plan (e.g., Schiel & Hickford 2001).

Very few subtidal soft-sediment epibiotic communities are monitored and practicalities associated with sampling these suggest that such sampling would need to be structured within biogenic habitats (see Section 6.3).

6.5 Deep-sea biological communities

At present collection of these data are generally conducted on an *adhoc* basis as required for specific commercial, MPI, GNS, University or NIWA projects. Two exceptions are the multiple, time-series sampling of benthic fauna that has occurred within the Graveyard Seamount complex (Clark & Rowden 2009; Clark et al. 2010; Williams et al. 2010) in 2001, 2006 and 2009 and eight sites sampled along a depth-transect (STF) on longitude 178.5° E across the Chatham Rise that have been re-sampled in 1997 (twice, autumn and spring), 2000 (summer) and 2001 (spring) (Nodder et al. 2003; Grove et al., 2006; Nodder et al. 2007). Sampling at these locations offers insights into the general structure and functioning of deep-sea biological communities in an international context. The STF transect in particular provides an opportunity for a long-term monitoring transect as it encompasses a range of depths, productivity and temperature regimes.

For reporting on change at a national level, monitoring at more locations around New Zealand would be required. At this stage we suggest that these extra locations should be nested within areas of change defined by the SST and ocean colour analyses. New, more cost-effective, technologies could also be employed, such as lander observatories and automated underwater vehicle surveys.

7 IMPROVEMENTS TO DATA COLLECTION AND STORAGE

There are a number of variables collected where the current diversity of different collection or analytical methods limit comparisons:

- Sediment grainsize,
- Sediment chlorophyll-a,
- Intertidal reef faunal and floral communities,
- Reef fish communities,
- Water clarity and suspended sediments.

While some standardisation could occur for the above variables, this is most likely to destroy present time series, as it is unlikely that a conversion factor could be applied. It would be more appropriate to determine the degree to which these differences alter the ability to detect changes, including the magnitude of the change that would be reported. While standard methods are generally a requirement for detecting changes, if present time series exist and if the degree of detectable change can be demonstrated to be not significantly different between methods, then maintaining these time series with different methodologies would not compromise national reporting. It would still be useful if new monitoring could use the best of the presently used methods, although choice of a method often depends on the reason for the data collection and cost efficiencies, e.g., turbidity, inorganic or organic suspended sediments may be collected for a number of different reasons. However, this is less likely to be the case for intertidal reef faunal and floral communities and reef fish communities, where standard techniques would be beneficial and little long-term monitoring presently occurs (e.g., Langlois et al. 2010, Schiel 2011, Wing & Jack 2013).

There are also areas where validation of existing data collection and analysis is needed: sea surface temperature, near-coast chlorophyll-a and particulate matter, and modelled currents and waves.

There are some concepts or terms that if standardised across the country could improve the efficacy of new monitoring. These terms include Biogenic habitats; Key species; and Sedimentary habitats.

Finally, there are improvements that can be made to data storage and sharing. Data sharing is still difficult, very little of the meta-data in the online meta-data catalogue is presently harvested from databases held in other organisations, thus actually gathering the data together for national reporting would take considerable effort. However, as most organisations are now working together to use standard protocols and databases that can be shared, over time this problem will be solved.

8 INTER-AGENCY IMPLICATIONS

8.1 Links to other central government initiatives

8.1.1 Statistics New Zealand

Two components of work conducted by Statistics New Zealand over the last few years are of importance to this programme. Firstly, the revised list of Tier 1 statistics includes the topic of “Marine Biodiversity” (approved for future use by Cabinet in August 2012) to be reported on five yearly with an entry date 2014/15, after an appropriate method for representing this has been developed (see Section 8.1.2). A new statistic on atmosphere and ocean climate change is also proposed, as is one for ecological integrity and diversity (see Section 8.1.4).

The second related component is the recently published Environmental Domain Plan (EDP, Statistics New Zealand et al. 2013). There are strong synergies between the Coasts and Marine topic domain plan and the Marine Environmental Monitoring Programme (MEMP) Project, with the project specifically being mentioned in many places in the plan. The three top initiatives considered from the Coastal and Marine topic were to identify baseline habitat state, expand statistical governance over coastal and marine data and review existing datasets. The first (CM1: identify baseline habitats) contains a list of potential parameters which overlaps well with those considered within MEMP, namely:

- water column and seafloor characteristics
- water composition (including productivity and pH)
- water temperature
- ecosystem health
- biodiversity
- benthic habitats (i.e., physical and biogenic)
- sensitive habitats
- fish populations

The other two top initiatives (CM2 and CM3) both mention the potential to build on MEMP. Other initiatives (CM4, 5, 8, 10, 12 and 18) also have strong links to MEMP. Importantly, of the ten topics considered in the EDP, three were specifically identified as having low degrees of required information. The coastal and marine topic was one of these three, showing “there is still a lot to discover and understand about the large fraction of New Zealand’s territory that is the marine environment”.

8.1.2 Ministry for Primary Industries

As well as the MEMP project, MPI has funded research investigating the potential of ecosystem indicators from trawl surveys and fish-stock indices (Dunn et al. 2009, Tuck et al. 2009). A suite of fish stock related indicators have previously been proposed for New Zealand state-of-environment monitoring (Gilbert et al. 2000) and discussion on these is on-going. Remote sensing, fisheries GPS and continuous plankton recording data have also been investigated for their potential to provide useful environmental indicators and an analysis both of available data and the implications of observed climate and oceanographic trends to fisheries has lately been completed (Hurst et al. 2012).

MPI is also the lead agency in the development of two new Tier 1 statistics. ‘Marine Biodiversity’ which is proposing optimal metrics for reporting on regional and national comparisons of biodiversity in terms of species numbers (per unit area), state of knowledge, and threat status. ‘Atmosphere and Ocean Climate Change’ will evaluate physical metrics that potentially drive patterns and changes in biodiversity (sea surface temperature, ocean acidification, net primary production, and sea surface height).

8.1.3 Ministry for the Environment

MfE has recently undertaken a review of monitoring for the RMA processes (Ministry for the Environment 2013), e.g., number of consents processed, time taken to process. MfE also explicitly excludes monitoring of the NZCPS as this is currently being considered as part of the Department of Conservation's monitoring design project. Thus, reporting on the marine environment by MfE is currently confined to three national environmental indicators, namely:

- marine areas with legal protection
- fish stocks under the Quota Management System and seabed trawling in deep waters
- recreational water quality at coastal swimming spots.

However, recently an environmental reporting bill has been proposed (New Zealand Parliament 2014. Environmental Reporting Bill, available at: http://www.parliament.nz/en-nz/pb/legislation/bills/00DBHOH_BILL12994_1/environmental-reporting-bill). This bill if passed would require regular reports on the state of New Zealand's environment as a whole, including the marine domain. The Bill focuses on using presently available data to derive information on the biophysical state of a domain, trends over time, pressures driving changes in the state, and the impacts of changes in the state on ecosystem integrity, public health, economic benefits derived from utilising natural resources, culture and recreation. Thus it overlaps with the intention of the MEMP in terms of variables that represent biophysical state, ecosystem integrity and ecosystem goods and services.

MfE is also involved as a participant at workshops associated with the MPI development of the new Tier 1 statistic 'Marine Biodiversity', and is continuing their involvement in development of estuarine classifications and guidelines. This project, which arose from the development of Land and Water Forum National Policy Statement on Freshwater Management is ongoing with DOC and is developing objectives and limits for estuarine health as part of the National Objectives Framework (NOF) under the National Policy Statement on Freshwater Management.

8.1.4 Department of Conservation

DOC is presently reviewing its marine reserve monitoring, with a view to standardising it around measures of ecological integrity. Their strategy centres round three phases:

1. Determining the environmental setting of and risks to specific Marine Protected Areas (MPA) to identify threats and categories of environmentally similar MPAs, (i) for future comparisons of their ecological status and (ii) to assist in the selection of MPAs for future monitoring. The types of information include visitor impacts, specific land-derived contaminants (e.g. sediments, heavy metals), proximity to aquaculture and other in-water engineered structures, the risk of exposure to fishing pressure and broad scale environmental drivers such as exposure, depth, slope and location in adjacent seascape.
2. Developing a standard set of habitat definitions that reflect the diversity and structure of seafloor habitats, e.g., kelp forests, sponge gardens, urchin barrens, *Atrina* beds, or shrimp burrow dominated habitats. Habitat types are to be related to function and include similar levels of detail for both soft and hard substrates, so that functional integrity can be assessed.
3. Selecting and surveying a sub-set of MPAs for validation of the monitoring strategy.

All three phases are largely completed , with reviewing now considering validation and ecosystem goods and services. The use of ecological integrity as a monitoring concept has been considered within the development of the MEMP and sits well within DOC's strategy. DOC is also leading the generation of a new Tier 1 Biodiversity reporting statistic "Ecological integrity and diversity".

In 2013, the DOC initiated a revision of the New Zealand estuarine classification as part of their Estuarine Work Programme. This is a collaborative project with NIWA and the University of

Canterbury. The new typology for New Zealand coastal systems, and associated terminology, will contribute to a range of uses such as awareness on estuarine system functioning, monitoring and research planning, representation and significance assessments, and decisions relating to restoration and protection. Together with the DOC/MfE project on developing guidelines and limits, this work will provide a consistent framework for national reporting and designing relevant monitoring in coastal systems, including estuaries.

8.2 Universities, Cawthron and NIWA

Increasingly, organisations that do research are becoming involved in marine environmental monitoring, either in developing frameworks and methods or in actually participating in data collection. Recent initiatives include:

- Oceans Science CoRE bid. This is a bid for a national educational centre, headed by the University of Otago, with the University of Auckland and NIWA as main partners. However, staff from the universities of Canterbury, Wellington and Waikato are also involved, as is the Cawthron Institute. Monitoring is a key part of this bid, including a theme on “Sentinel monitoring” which involves both sentinel species and sites, and a sub-theme involving the development of a distributed national sampling network for acidification.
- A Cawthron initiated discussion on a strategy for development of a near-shore coastal mooring network (Ellis et al. 2012) as an extension of Land, Air, Water Aotearoa (LAWA).
- NIWA discussions with TranzRail over using the InterIslander for surface water sampling across Cook Strait.

9 SUMMARY

9.1 Suggested monitoring

The monitoring suggested here is predominantly based on existing data collection in New Zealand and is largely consistent with marine environmental monitoring programmes around the world. One difference is the lack of emphasis on “key” species or habitats, driven by lack of a national consensus in New Zealand on what these are. In accordance with many international programmes emphasis is placed on data collected over a range of spatial and temporal scales, from continuous coverage through to point measures.

The variables suggested for monitoring in Section 5 cover various aspects of physics, chemistry and biology. Generally they are variables which integrate over small time scales and for which research has demonstrated both strong links to other components of the ecosystem and strong responses to anthropogenic stressors. At present, relatively small extensions in data collection, together with the development of analytical and reporting techniques, could result in robust national-level reporting of changes in:

- sea level, including changes in tide range and storm surge (intensity, frequency), and responses to ENSO/IPO;
- sea-surface temperature across the EEZ and territorial sea;
- sea-surface chlorophyll-a as a surrogate for primary productivity in offshore waters;
- suspended particulate matter in nearshore waters;
- macroinvertebrate biodiversity, sediment primary productivity, urban and nutrient contamination , and health of estuaries and harbours;
- demersal fish biodiversity, size structure and trophic dynamics in the nearshore and midwater offshore
- presence and abundance of non-indigenous species.

These variables contribute to information on a number of issues identified as being important to report on at a national level[5]:

- physical and chemical trends in the environment especially those related to climate change, fishing, increased sediment loading and turbidity, discharge of contaminants, increased nutrients, dumping of dredged sediment, mining and aquaculture;
- ecological status as health, integrity, resilience and ecosystem goods and services; and
- productivity.

Marine environment components that are often (but not always) monitored elsewhere in the world that would require considerable investment, both in terms of research and funding in New Zealand include:

- Water chemistry of both the near-shore and off-shore, especially ocean acidification measurements as recommended by the Global Ocean Acidification Monitoring Network http://www.pmel.noaa.gov/co2/GOA-ON/, at representative sites that are important ecologically, culturally and economically to New Zealand. This data is crucial to monitoring change associated with landuse changes, marine pollution and climate change.
- Midwater fish, phytoplankton and zooplankton biodiversity, in particular extensions to the CPR monitoring, would be useful to monitor change associated with extractive industry activities and climate change and would be relevant to assessing ecosystem goods and services and ecological integrity.
- Sedimentary and biotic habitats. This data would be directly relevant to reporting on changes to ecosystem goods and services or ecological integrity.
- Coastal ecological communities associated with rocky reefs and soft-sediments, including fauna, flora and fish. This data would be useful to monitor change where many New Zealanders have their primary contact with the marine environment and would be relevant to reporting on changes to ecosystem goods and services or ecological integrity.
- Deep sea benthic biodiversity. This data would be directly relevant to reporting on changes to New Zealand biodiversity, ecosystem goods and services or ecological integrity.

At present, the most important of these is water chemistry. The others are all important ecosystem responses to changing physical and chemical conditions. Habitats have the most hurdles to overcome in terms of methodological development and the coastal ecological communities would probably be the cheapest to implement. However, an argument can be made that it is particularly important to include deep sea benthic habitats and biodiversity in a national monitoring programme because of the extent of area they cover. That is, any combined effect will be of high importance (Smith et al. 2013).

Monitoring of only a few direct stressors has been considered here as essential for monitoring. Monitoring of most of the anthropogenic stressors operating on New Zealand's marine environment is not generally undertaken (MacDiarmid et al. 2012a), although Maritime NZ is tasked with determining the number of oil spill events and MPI map the distribution and intensity of seabed fishing effort (Baird et al. 2011) and monitor catch. While it is important to monitor stressors, allocation of effort to monitoring the stressors frequently leads to an imbalance in monitoring, where the activity but not its outcome is adequately monitored. That is, the presence of stressors is known but not how great an impact they are having.

That said, climate change in particular was identified by many participants in this project as having a substantial potential effect on New Zealand marine ecosystems. Climate associated change to New Zealand's marine environment includes: rising sea levels, changes to sea temperature, wind, waves and freshwater input regimes, changes to upwelling, ocean circulation (currents), water column stratification and ocean acidification (note that ocean acidification figures strongly in the IPCC Fifth Assessment Report recently released http://www.ipcc.ch/report/ar5/). Monitoring of wind, rainfall and freshwater

[5] Note that information on non-indigenous species is already reported at a national-level

inputs are not a focus of this project; monitoring of the others, either directly (e.g. acidification, sea level, temperature, winds and currents) or indirectly (upwelling, circulations) have all been discussed.

9.2 Implementing monitoring and analysis

While the suggested monitoring relies strongly on data that are already being collected, currently it is not possible to use them all for reporting purposes. A number of steps are first required.

- Validation of remotely sensed sea surface chlorophyll-a and particulate matter in the coastal region of New Zealand. A number of different processing methods are available for the estimation of chlorophyll-a from ocean colour data. The "best" algorithm depends on the type of sensor and this has changed from the initial CZCS sensor (24/10/78 – 22/6/86), through SeaWiFS (01/08/97 – 14/02/11) to MODIS-Aqua (4/5/02– ongoing). The consistency of the chlorophyll-a estimations has been examined for these sensors globally, but should be tested specifically for New Zealand regions, at least for SeaWiFS and MODIS-Aqua. Similarly, sea-surface particulate matter estimates need validation. Moreover, the implications of not collecting extreme data (due to cloud cover during rain events), or understanding subsurface suspended sediment flows, needs to be evaluated.

- Determination of reporting areas for remotely sensed data. Analysis of present data needs to be undertaken to determine reporting areas for sea-surface height, temperature, chlorophyll-a, suspended sediment and any other remotely sensed variables. Analysis to determine reporting areas of satellite ocean colour data has been completed for the north-east New Zealand shelf (Chiswell et al. 2013, Richardson et al. 2002) and the analysis is being extended to the EEZ-scale (Kennan, pers. com.).

- Extension of sampling: for the Coastal Sea Level Network (two sub-regions of the country currently are not monitored); the Demersal fish monitoring (the northeast and west coast of the North Island need monitoring locations); and the Estuaries monitoring both spatially (estuaries on the west coast of the South Island) and temporally (more estuaries need to be monitored on an annual or seasonal basis).

- Validation of the suggested analytical technique for the Estuaries monitoring (creation of a national benthic health model) and continued development of some type of functional index.

Finally, development of an analytical and reporting framework would be required.

9.3 Areas where research is needed

This project revealed many areas where research is needed if effective monitoring is to be undertaken.

- Measurement of nutrients (especially nitrate) in the upper ocean. Recently, instruments have been developed for automated measurement of oceanic nitrate, for example, the ProPS-UV submersible UV process photometer (TRIOS, www.trios.de). Research is underway in New Zealand to test the efficacy of such sensors (Cliff Law, NIWA, pers. comm.). If measurements from this type of sensor are found to be robust and of the required accuracy, monitoring of upper ocean nutrients could be possible from ships of opportunity or other cost-effective platforms in the future.

- Development of robust, inexpensive methods to measure sedimentation rates and suspended sediment near the sea bed.

- Cost effective habitat mapping techniques for biogenic and sedimentary habitats are required. It is likely that any such techniques will need to be a hierarchical combination of broad-scale remote assessment (varying from photographic imagery from satellites, planes or drones in intertidal/shallow waters to multibeam in deeper waters, supplemented by video transects and traditional point sampling (Bowden & Hewitt 2011, Hewitt et al. 2004). Research is also needed to determine how information from one scale can best be related to the other scales and to create algorithms for processing the acoustic data.

- Research is needed on appropriate monitoring techniques to determine abundances in the populations of threatened, at risk and protected species. We know very little about the distribution of marine mammals around NZ, although more use could be made of the existing sightings and environmental data to model habitat use patterns of many species. An effective and informative monitoring method for the presence of cetaceans around New Zealand would be the deployment of acoustic loggers which record their vocalizations. Similarly, many seabird species remain poorly studied and we know little about population sizes and at-sea distributions for the majority of New Zealand taxa. As a first step, regular and standardised observations of seabirds (and marine mammals and other protected species) from research vessels, where possible, could build a valuable, long-term observational data set that would advance our understanding of the distributions and habitat-use of a wide range of species.

- Relative sea-level rise around the New Zealand coastline is likely to be highly variable temporally (due to climate variability and climate-change) and also spatially variable arising from subsidence or uplift of coastal margins. For example, Wellington and the lower North Island is currently subsiding at 1–3 mm/yr compared with the present NZ-wide average rise of 1.7 mm/yr in sea level (Beavan & Litchfield 2012), resulting in a larger sea level rise in this area. At present, the local relative sea-level rise has increased two-fold due to slow seismic slip activity in lower North Island over the past decade or more. To this end, the continuous GPS monitoring network funded by Land Information NZ through the GeoNet monitoring programme, will be a source of ongoing information on vertical land movement at various sites around New Zealand that will allow sea-level rise to be extracted from locally-measured relative sea-level rise. At present, investigations of long-term sea-level records are regionally driven and generally funded through commercial contracts. Strategic research planned at a national scale is needed to tie this information together and to downscale from global projections to local changes in sea level around the country, and include the influence of changes in extremes (e.g., storm surges, waves).

- Finally, it is worth noting that chemical contaminants entering the sea are continually changing. It is important to keep track of “emerging” contaminants and assess the likely risk for the marine environment. Of probable importance in the future, that we presently know little about, are microplastics and estrogen mimics.

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Appendix 1: List of legislation and strategic plans reviewed by Froude (2013) for information on concepts and variables that could be important for reporting on at a national level. Information requirements generated by the Environmental Domain Plan and the Draft Environmental Reporting Bill are included directly in the introduction and Section 8.

Fisheries Act 1996
Fisheries 2030
Ministry of Fisheries Statement of Intent 2011–2014
Resource Management Act 1991
New Zealand Coastal Policy Statement 2010
Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2013
Conservation Act 1987
Marine Reserves Act 1971
Reserves Act 1977
Wildlife Act 1953
Marine Mammals Protection Act 1978
Hauraki Gulf Marine Park Act 2000
Marine and Coastal Area (Takutai Moana) Act 2011
Fiordland (Te Moana O Atawhenua) Marine Management Act 2005
New Zealand Biodiversity Strategy 2000
Conservation General Policy 2007
Marine Protected Areas Policy and Implementation Plan 2005
Department of Conservation Outcomes Model
(Conservation) Plan Blue 2011
Biosecurity Act 1993
Pest Management National Plan Of Action 2011
Maritime Transport Act 1994
Maritime Transport (Marine Protection Conventions) Order 1999

Appendix 2: Ecosystem services.

Note that a category of goods (or provisioning services) associated with food, raw materials and genetic and medicinal resources are often also included (e.g. Beaumont et al. 2008).

Over-arching Categories	Ecosystem Goods and Services
Regulating services	Disturbance prevention Waste treatment, processing and storage Water regulation Sediment retention Biological control Gas and climate regulation Nutrient regulation
Supporting services	Resilience and resistance Habitat structure
Cultural services	Cultural and spiritual heritage Leisure and recreation Cognitive benefits Non-use benefits Speculative benefits

Appendix 3: List of those involved in determining the structure of the meta-data catalogue.

Most work was done at a workshop, 14th December 2011, although a record of the meeting was distributed for comment to representatives of the University of Auckland and Regional Councils who could not attend. See Appendix 3 Table 1 for workshop members.

Appendix 3 Table 1: Members of workshop for determining the structure of the meta-data online catalogue.

Organisation	Attendee
MPI	Mary Livingston Rich Ford
MfE	Janine Smith
DOC	Ann McCrone Peter Heimstra
NZ Geospatial Office	John Forne
NIWA	Judi Hewitt Brent Wood Alison MacDiarmid Rob Bell
Cawthron Institute	Joanne Ellis
Victoria University of Wellington	Jeff Shima
University of Waikato	Conrad Pilditch
Pacific Eco-Logic Ltd	Vicky Froude
University of Auckland	Mark Costello
Regional Council Special Interest Group, Coasts	Jarrod Walker

Appendix 4: Initial database correspondents.

In October 2011, a message summarising the project and asking for information about time series databases on the marine environment was sent to:

- Conrad Pilditch Waikato University
- Daniel Kluza Biosecurity MPI
- Brendan Gould Biosecurity MPI
- Jeff Shima Victoria University
- Debbie Freeman DOC
- Megan Carbines Auckland Council
- David Schiel Canterbury University
- Ann McCrone DOC
- Sarah Clarke PCE
- Nick Shears Auckland University
- Brian Paavo, Benthic Science Ltd
- Keith Hunter Otago University
- Catriona Hurd Otago University
- Keith Probert Otago University
- Lesley Bolton-Ritchie Canterbury Regional Council
- Juliet Milne Greater Wellington Regional Council
- Richard Griffiths Northland Regional Council
- Anna Madarasz-Smith Hawke Bay Regional Council
- Hilke Giles, Waikato Regional Council
- Jarrod Walker representative of the Regional Councils Coasts Special Interest Group

Appendix 5: Meta-data vetting.

The following meta-data characteristics were used to determine whether the data base would be useful for national reporting of the marine environment.

1- Use of data must be permitted

2- There must be some form of quality assurance of data entry and measurements

3- Meta information must be available for all required fields, e.g.,

   a. Geographic scope area or latitude and longitude

   b. Number of locations

   c. Completeness, i.e. are all locations always sampled for all variables

   d. Sampling frequency

   e. High level habitat keywords identifying which of the following the data covers (water column, benthic hard, benthic soft, seamount)

   f. A list of measured variables

4- Use of standard or well documented methodologies with references

5- The programme should be ongoing although finished programmes may be incorporated later in the process if the location or type of data are considered important.

6- Data must include at least 3 repeated measures at same location at least one year apart

7- Standardised season (or month) of sampling

Appendix 6: Details of work done to produce a list of variables for detailed consideration.

Scientists with expertise in a variety of marine disciplines (e.g., oceanography, ecology, chemistry, fisheries, hydrodynamics) from research institutes, universities, New Zealand government departments and environmental engineering consultancies) were invited to be part of the variables identification working group (Appendix 6 Table 1). The main product of this workshop was a list of variables covering broad environmental classes and disciplines: water (from the surface to the seafloor); seafloor; nearshore (including estuaries), offshore.

Appendix 6 Table 1: List of science and management related personnel contacted during the production of the list of variables for detailed consideration. "Workshop" indicates those asked to the workshop, and "Questionnaire" indicates questionnaire respondents.

Person	Organisation	Expertise	Workshop	Questionnaire
Jarrod Walker	Auckland Council	Coastal Scientist	Y	Y
Joanne Ellis	Cawthron Institute	Soft sediment benthos and impacts	Y	Y
Shane Kelly	Coast & Catchment Ltd	Coastal contamination	Y	Y
Debbie Freeman	DOC	Marine scientist	Y	
Mary Livingston	MPI	Fisheries	Y	Y
Rich Ford	MPI	Fisheries, Coastal Ecology	Y	Y
Alison MacDiarmid	NIWA	Coastal Ecology, Impact Assessment	Y	Y
Chris Hickey	NIWA	Contaminants and ecotoxicology	Y	Y
Cliff Law	NIWA	Physical oceanographer	Y	Y
Dave Bowden	NIWA	Deep sea benthos	Y	Y
Graeme Inglis	NIWA	Biosecurity	Y	Y
Ian Tuck	NIWA	Benthic impact standards	Y	Y
John Zeldis	NIWA	Coastal nutrients and oceanography	Y	Y
Judi Hewitt	NIWA	Benthic ecology, statistics	Y	Y
Malcolm Clark	NIWA	Deep sea biodiversity	Y	
Malcolm Francis	NIWA	Fish distributions	Y	Y
Matt Pinkerton	NIWA	Remote sensing	Y	
Owen Anderson	NIWA	Fisheries	Y	
Phil Boyd	NIWA	Oceanography	Y	

Phil Sutton	NIWA	Physical oceanography	Y	
Richard O'Driscoll	NIWA	Fisheries	Y	
Rob Bell	NIWA	Hydrodynamics	Y	Y
Scott Nodder	NIWA	Sediments and marine foodwebs	Y	Y
Simon Thrush	NIWA	Benthic ecology	Y	Y
Wendy Nelson	NIWA	Taxonomy, macroalgae	Y	Y
Vicky Froude	Pacific Eco-Logic Ltd	Indices; linking science & policy,	Y	Y
Mark Costello	University of Auckland	Biodiversity	Y	Y
Nick Shears	University of Auckland	Kelp forests, rocky reefs, climate change	Y	Y
David Schiel	University of Canterbury	Rocky reef ecology, aquaculture	Y	
Candida Savage	University of Otago	Estuarine food webs and isotopes	Y	
Catriona Hurd	University of Otago	Macroalgae	Y	Y
Kim Currie	University of Otago	Oceanography	Y	
Conrad Pilditch	University of Waikato	Benthic oceanography	Y	Y
Jeff Shima	Victoria University of Wellington	Quantitative ecology, especially fish	Y	

After this meeting, information on international marine environmental monitoring programmes was gathered and used both to extend the list (see Appendix 6 Table 2) and to provide information on the relative frequency of programmes (external to New Zealand) monitoring each variable. The online meta-catalogue was used to determine the how widely each variable was presently monitored within New Zealand. This information was provided with a questionnaire which was sent out to the working group members asking them to:

1. Rank the variables in one or more areas (biological, sedimentary, water) in order of importance for a national monitoring programme, using the following criteria to provide a single rank:
    i. Is not confined to particular geographical locations (e.g., mangroves are confined to northern New Zealand);
    ii. Contributes to reporting across a breadth of priority national environmental outcomes;
    iii. Can be measured regularly and consistently over time;
    iv. Has existing knowledge of temporal and spatial variance and controlling factors;
    v. Is known to be sensitive to a number of pressures or one important one (i.e., change clearly represents an improvement or deterioration in the environment);
    vi. Is representative of the larger ecosystem;

2. Provide information on:
    - Whether the measurement technique that is standard or only in development
    - Can it be measured in New Zealand by field personnel, a number of laboratories, or does it require specialised measurement or analysis?
    - Whether problems have been found in the past with measurement of the variable that would need to be overcome?
    - Is there a better or newer variable that should be used instead?
    - Does the variable represent more than just itself (e.g., sea level rise indicating climate change)?
    - Can the variable be used in conjunction with other variables as a measure or indicator of something else?
    - Any other comments?

There were at least ten respondents for each of the three categories covering a number of organisations (see Appendix 6 Table 1). Responses were analysed to determine the top ten ranked variables in each category. This was done by (a) creating an average rank across all respondents and (b) calculating the number of times a variable was ranked in the top ten.

Appendix 6 Table 2: List of variables discussed by the working group.

Biological

- Habitats- Change in extent, e.g., aragonite and calcite shelled animal habitat, biogenic 3D habitat, kelp forest, urchin barrens, Large brown algae, Seagrass, Mangrove, Wetlands
- Exploited species- Size, age, reproduction
- Demersal fish communities
- Pelagic fish communities
- Reef fish communities
- Distribution and abundance (or biomass) of key species- e.g., seagrass, rock lobster, cockles, blue cod and corallines were mentioned
- Growth rate of key species
- Size, age, reproduction of key species
- Marine mammal abundances
- Marine mammal/seabird reproductive rates
- Marine mammals size structure
- Numbers of threatened or at risk species
- Number of individuals of protected species
- Numbers of non-indigenous species
- Phytoplankton dominance and biomass
- Beach faunal communities
- Reef floral and faunal communities
- Sheltered soft sediment macroinvertebrate communities
- Soft epibiotic communities
- Species with boundary in EEZ that might change as water properties change
- Subtidal estuarine fish communities
- Top predator guild species
- Zooplankton dominance and biomass
- Tissue contaminants (cadmium, chromium, copper, lead, zinc, PAHs, PCBs, OCPs, arsenic, radioactivity)
- Tissue stable isotopes

Sediment

- Sediment grainsize
- Chlorophyll-a

- Nitrogen as nitrates and ammonium
- Total Organic Carbon
- Zinc
- Redox depth
- Sedimentation rate by traps
- Sedimentary habitats (e.g., mud, sand)
- Copper
- Sediment accumulation on plates
- Lead
- Inorganic and organic carbon by loss on ignition
- Beach profiles and waves by Cam-Era
- Cadmium
- Arsenic
- Polyaromatic hydrocarbons
- Beach profiles
- Phosphates
- Organic contaminants
- Mercury
- Nickel
- Chromium
- Total Phosphorus
- Antimony
- Silver

Water

- Sea surface temperature
- Sea level
- pH
- Sea Surface chlorophyll-a
- Water column integrated chlorophyll-a
- Turbidity
- Currents
- Primary production
- Dissolved inorganic carbon
- Ammonia (NH_4)
- Wave buoy
- % dissolved oxygen
- Temperature near bottom
- Total Nitrogen (TN)
- Nitrate (NO_3)
- Dissolved oxygen (mg/l)
- Nitrate + Nitrite
- Temperature at mid depths
- Nitrite
- Salinity
- Suspended solids
- Light
- Lead
- Total phosphorus
- Particulate nitrogen
- Copper
- Colour

- Zinc
- Depth
- Wave activity near bottom
- Conductivity
- Tidal gauging
- Total kjeldahl nitrogen
- Dissolved reactive phosphorus
- Dissolved organic carbon
- Total organic carbon
- Particulate organic carbon
- Particulate phosphorus
- Chromium
- Suspended particulates near seafloor
- Nickel
- Silicates
- Chloride
- Iron
- Particle flux
- Black disk
- Secchi disk
- Volatile suspended solids
- Cadmium
- Salinity near bottom
- Aluminium
- Calcium

Highest agreement was found between respondents for the biological variables, with all 12 respondents placing soft-sediment macroinvertebrate communities in their top ten ranks. Respondents for sediment and water variables were also relatively consistent, with 11 of the 12 ranking sediment grainsize in their top ten ranks and 9 of the 10 respondents placing sea surface temperature in their top ten ranks.

The list of thirty-five variables selected by this process (Appendix 6 Table 3) was sent to an expanded group for confirmation (see Appendix 6 Table 4). It was also advertised on the NZMSS website (nzmss.org/).

Appendix 6 Table 3: The prioritised list of variables, in the three categories (biological, sedimentological and water), together with their average rank given by respondents, where 1 = highest priority.

Biological		Sediment		Water	
	Average rank		Average rank		Average rank
Soft-sediment macroinvertebrate communities	2.5	Sediment grainsize analysis	3.3	Sea Surface temperature	4.4
Biogenic habitats	5.6	Chlorophyll-a	7.5	Sea level	5.9
Reef floral and faunal communities	8.5	Sedimentation rates	8.6	Surface chlorophyll-a	7.5
Numbers of threatened, at risk or protected species	9.3	Nitrogen	8.7	pH	7.5
Non-indigenous species	11.8	Organic content	9.8	Turbidity or Suspended sediments	10.9
Soft-sediment epibiotic communities	11.9	Zinc	11.2	Nitrate or nitrate plus nitrite	11.2
Distribution of key species	12.3	Redox	11.8	Dissolved oxygen at mulitple depths	12
Reef fish communities	13	Copper	12.3	Current velocity fields	12.6
Demersal fish abundance	14.8	Sedimentary habitats	12.3	Dissolved inorganic carbon	13.5
Zooplankton dominants and biomass	14.9	Lead	12.5	Ammonia (NH_4)	14
Phytoplankton dominants and biomass	14.9	Beach erosion	13.1	Wave climate	14.1
		Cadmium	14.7	Temperature near bottom	14.6

Appendix 6 Table 4: List of persons contacted to review the reduced list of variables.

Person	Organisation
Marcus Cameron	Auckland Council
Megan Carbines	Auckland Council
Armagan Sabetian	Auckland University of Technology
Len Gillman	Auckland University of Technology
Brian Paavo	Benthic Science Ltd
Paul Gillespie	Cawthron Institute
Rowan Strickland	Cawthron Institute
Tim Haggitt	Coastal and Aquatic System LTD
Kevin O'Connor	Department of Conservation
Bruce Williamson	Diffuse Sources Ltd
Steven Park	Environment Bay of Plenty
Lesley Bolton-Ritchie	Environment Canterbury
Greg Larkin	Environment Southland
Judith Robertson	Gisborne District Council
Juliett Milne	Greater Wellington Regional Council
Megan Oliver	Greater Wellington Regional Council
Anna Madarasz-Smith	Hawke's Bay Regional Council
Barry Gilliland	Horizons Regional Council
John Wright	Institute of Environmental Science Research (ESR)
Nicholas Dickinson	Lincoln University
Steffi Henkel	Marlborough District Council
Gaven Martin	Massey University
Marti Anderson	Massey University
Claire Gregory	MfE
Dorothee Durpoix	MfE
Tom Bowen	MfE
Brendan Gould	MPI

Simon McDonald	MPI
Tim Riding	MPI
Phillip Boyd	NIWA
Don McKenzie	Northland Regional Council
Irene Middleton	Northland Regional Council
John Ballinger	Northland Regional Council
Richard Griffiths	Northland Regional Council
Rachel Ozanne	Otago Regional Council
Fleur Tiernan	Resourcee and Environmental Management Ltd
Emily Roberts	Taranaki Regional Council
Trevor James	Tasman District Council
Andrew Jeffs	University of Auckland
Murray Ford	University of Auckland
Paula Jameson	University of Canterbury
Abby Smith	University of Otago
Stephen Wing	University of Otago
Chris Battershill	University of Waikato
Catherine Beard	Waikato Regional Council
Hilke Giles	Waikato Regional Council
Vernon Pickett	Waikato Regional Council
Jonny Horrox	West Coast Regional Council
Michael Meehan	West Coast Regional Council
Barry Robertson	Wriggle Coastal Management Ltd

Appendix 7: The list of questions and results of structured phone conversations with policy representatives from MPI, MfE, DOC, LINZ, EPA, MED-Tourism, MFAT, Maritime New Zealand, Statistics New Zealand and regional councils.

The following questions were asked:

- What are you required to report on?
  - Are you satisfied with what is monitored?
  - If yes, which monitoring elements are particularly useful?
  - If no, what do you feel you need?
- Are you interested in trends related both to human influence and to natural patterns?
- Do you need information on changes in response to climate change? If so, which aspects do you feel are important?
- Do you need to relate observed trends to ecosystem health, functioning or value?
- Do you report on pre-existing indicators, specific physical, chemical or ecological parameters?
- What spatial (e.g. national, regional, specific locations) scales do you need to report at?
- What temporal scales (e.g., annual, five yearly) do you need to report at?

Each interview was documented and summarised by tabulating the numbers of organisations that were interested in the same issues and scales of reporting.

Policy requirements of local and national government bodies related to marine environmental monitoring were variable. While some organisations required very specific information which is not included in this project (e.g., Maritime New Zealand needs to monitor dumping of dredge spoils, DOC needs to monitor effectiveness of marine reserves and the NZCPS, MPI needs to monitor fish stocks others did not have any statutory requirements to report on trends in the marine environment (e.g., MED- Tourism, LINZ) and the EPA does not currently have monitoring and reporting requirements. MfE had 22 indicators that they report on, few of which are marine and the focus of Statistics NZ reporting was recently broadened to include marine biodiversity and ocean climate change. Very few correspondents stated that present monitoring was sufficient for their needs.

All eight of the organisations surveyed were interested in natural temporal variability of the marine environment (both cycles and trends) and seven were interested in detecting trends in the marine environment associated with human impacts, specifically the following:

- Fishing
- Sedimentation
- New energy and minerals exploration and development, specifically as they affect fisheries
- Dumping including accidents (e.g., garbage, oil, dredged sediment)
- Contaminants in sediment and water
- Non-indigenous species

Most organisations specified an interest in effects of climate change on the marine environment. Not included in the original replies, but likely to also be of interest are land-use activities, nutrient enrichment and diseases.

Legislation does not mention specific aspects of the marine environment as requiring consideration, with the exception of the New Zealand Coastal Policy Statement (NZCPS) 22, which requires assessment of increases in sedimentation rates. Instead more general statements such as “environment”, “natural resources or environment”, “physical resources”, “habitats” and “ecosystems are used (Appendix 7 Table 1). Generally these terms did not specify the marine environment, but specific requirement to monitor the “coastal environment” is in the RMA and in the National Coastal Policy Statement.

More specific terms were also mentioned (Appendix 7 Table 1), with “biodiversity” and “water quality” in the purview of most agencies. “Ecosystem services”, “Ecosystem functioning” and “Ecosystem health” when amalgamated into a single category was also in the purview of a number of agencies.

While EPA and MED Tourism were not specifically required to monitor, the EPA respondent stated the EPA would expect to see terms such as “Ecosystem function” and “Ecosystem health” used when assessing changes to the marine environment, and MED Tourism said they felt that information on changes in “Protected, threatened or endangered species” and “Water quality” was important.

Appendix 7 Table 1: Environmental terms used in New Zealand legislative requirements of central and local government agencies. Note that these terms generally apply to terrestrial, freshwater and marine environments without specification.

Environmental terms
Environment
Natural resource
Physical resources
Ecosystems
Habitats
Biodiversity
Significant habitats (faunal and floral)
Ecosystem services
Ecosystem function
Trophic linkages
Ecosystem health
Water quality
Life supporting capacity
Important fish habitats
Invasive species and pests
Protected, threatened or endangered species
Sedimentation rates