Ministry for the
Environment
Manatū Mō Te Taiao

Environmental
performance
indicators

Technical Paper
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Environment

Potential coastal and estuarine indicators –
a review of current research and data.

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Signposts for sustainability

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1 INTRODUCTION

The Ministry for the Environment's Environmental Performance Indicator Program (EPIP) is developing a core set of national environmental indicators for New Zealand's coasts and estuaries. As a first step in developing these indicators the Ministry needed to consult with New Zealand's coastal and estuarine scientists to identify potential indicators from the existing scientific knowledge base. The Ministry is interested in what is currently able to be measured and areas that need further research, and also databases that are available from which information can be obtained for the development of indicators.

Ton Snelder (NIWA Christchurch) and Jonet Ward (Lincoln Environmental) were employed by the Ministry for the Environment to hold a series of meetings around New Zealand with some coastal and estuarine researchers from universities and research organisations. At these meetings the Ministry outlined the EPIP and the approach to developing indicators was discussed. The researchers were then asked to outline their expertise, the research they were involved with and research they were aware of that could be useful in the context of the Ministry's EPIP.

Meetings were held during September 1997 at the University of Otago, NIWA in Wellington, NIWA in Hamilton, the University of Auckland and the University of Canterbury. A list of attendees at these meeting is appended.

The aim of these meetings was to obtain information and databases on research carried out in New Zealand on coasts and estuaries that could be relevant to the development of a core set of national environmental indicators.

2 KEY ISSUES IDENTIFIED

A number of key issues were identified during the meetings. These issues either present significant constraints on our ability to develop rigorous indicators for the coastal environment or highlight where further work is required to develop a system within which the indicators will work.

2.1 Diversity of New Zealand's Coastal Environment

New Zealand's coastal environment covers a wide range in latitude and climatic regions. It is also influenced in different regions by different ocean currents and geomorphic processes. This results in a wide diversity of coastal environments which support different types of biological communities. This presents a significant challenge for developing a national set of environmental indicators as environmental conditions will vary depending on the type of environment in question.

2.2 Lack of Scientific Knowledge

The consensus opinion by experts at the meetings was that there is a basic lack of knowledge about coastal biology and ecology in New Zealand's coastal environment. Coastal plant and animal communities can be naturally highly spatially and temporally variable. There is a lack of knowledge about the causes of this variability. An example of this is the lack of recruitment success of some coastal species. Reproduction of some crab species for example can be entirely unsuccessful for a number of years (Dr Colin McLay, University of Canterbury). This type of variability makes it very difficult to assess the state of a coastal ecosystem at any given point in time because separating natural variability from changes caused by anthropogenic effects is hard if not impossible (at present) to do. The comment was made by Dr David Schiel at the University of Canterbury that in general terms, a change in a coastal community of 50% was required before one could be statistically certain that the measured change had been induced rather that being an artefact of natural variability. This required magnitude of change would make temporal monitoring of coastal communities a very "blunt" indicator of changes in the ecosystem.

2.3 Lack of Existing Indices of Ecological Health

In some environments a range of indices have been derived that provide an overall measure of ecological health relative to pressures exerted by human activities. A well understood example is the freshwater macro-invertebrate index (MCI) which "scores" the biological community in a river relative to organic contaminant inputs. The MCI index is commonly used to report on the relative health of rivers as a surrogate for the river ecosystem as a whole. The consensus of opinion amongst the invertebrate specialists at the meetings was that there is currently insufficient information available to develop this type of index for marine species. It would take a considerable amount of research to develop such an index and this is unlikely to occur in the near future.

It is noted that an inability to attach an index of health to invertebrate communities should not be confused with the use of benthic macro-invertebrates for assessing effects at a site. Differences in benthic macro-invertebrates at an impact site relative to a suitable reference site are useful indicators of impacts where a reference site is used to separate natural variability from induced change. Thus this type of information is useful at a very small scale but not very helpful regionally or nationally.

2.4 Coastal Classification Systems

Part of developing a set of indicators might involve a coastal classification system which can be used to identify indicators which are appropriate to a particular type of coastal environment. In addition, classification may be required in the interpretation of measurements to understand how a particular aspect of the environment varies from its "natural" state.

2.5 The Current State of Coastal Environments and Monitoring Effort

The view was expressed by a number of the researchers that, in general terms, New Zealand's coastal environment is in a "healthy state". Specific impacts are occurring at certain locations. Examples cited were sediment impacts from land runoff, stormwater discharges, sewerage outfalls, marine dredging and dumping, impacts from fishing activities, impacts on rocky intertidal areas by trampling and harvesting and impacts from poor practices such as the dumping of soil on coastlines. In some circumstances these are being monitored. However the state of these impact locations cannot be extrapolated to accurately represent the state of the coastal environment in general terms.

Scepticism was expressed that more resources would be committed to improve coastal monitoring by regional councils. The view was put that a core set of indicators would be most useful if it enhanced the effort that is currently being spent on coastal monitoring.

3 DEVELOPMENT OF INDICATORS

The Ministry for the Environment is assuming two fundamental goals for coastal management:

- To maintain the life supporting capacity or “health” of aquatic ecosystems;
- To sustain human uses and values.

These goals lead to the development of two types of indicators; those of ecosystem health and those of human uses and values. People value the coastal environment for a variety of recreational and commercial uses, for its natural character including landscape quality and ecology, and for clean water and safe seafood.

Environmental indicators provide information on the state of, or pressures on, certain components in the environment. To provide a framework within which to discuss the issues or potential indicators that were raised at the meetings, we have divided the coastal environment into a number of environmental components. The issues or potential indicators are summarised in Table 1 and discussed more fully in the following sections. They are separated into one of four categories in terms of their usefulness as indicators:

1. Ready to use now as an indicator;
2. Basic research has been done from which an indicator can be developed;
3. Promising as an indicator but more fundamental research is required;
4. Not worth pursuing as an indicator because of lack of relevance to the National Environmental Performance Indicators Programme.

For each issue or potential indicator, justification for the category is given along with key contacts and any references.

The proposed indicators are not divided into estuaries, harbours, open coasts etc in this report because an appropriate classification system is not yet available. Some indicators will be common to both estuarine and coastal waters while others will apply to only one part of the coast such as the deep water communities.

Table 1
(At back of document)

3.1 Potential Indicators of Ecosystem Health

3.1.1 Water Column

Oxygen (per cent saturation) is a good indicator of ecosystem health and well understood.
Category 1, ready to use.
Contact: Dr John Jillett, University of Otago
Dr Bill Vant, NIWA Hamilton

Water clarity is another good indicator of ecosystem health, easy to measure and appropriate in many situations - change in turbidity may be the appropriate indicator.
Category 1
Contact: Dr Bill Vant, NIWA Hamilton

Phytoplankton is considered a potential indicator by some scientists and not by others. Fluoresence monitoring can now be continuous and would cover the need to monitor nutrients as these are reflected in the phytoplankton. Requires expertise.
Category 1 or 4
Contact: Dr Bill Vant, NIWA Hamilton
Mr Rodney Roberts, Cawthron Institute

Toxic algal blooms, routinely surveyed by Cawthron Institute, are caused by enhanced nutrients, warm water temperatures and low wind conditions. Intensity of outbreaks are monitored and once there has been an outbreak the cysts remain in the sediments until conditions are suitable. The Marine Biotoxin Programme is co-ordinated from Wellington. It is an inter-disciplinary programme where the toxin is identified by ESR, analysed by Cawthron and involves the Health Department.
Category 1
Contact: Dr Lesley Rhodes or Mr Lincoln McKenzie, Cawthron Institute
Dr Islay Marsden, University of Canterbury

Planktonic assemblages can be monitored to distinguish coastal from open waters using copepod groups for example. This is a specialist application and may not be relevant.
Category 4
Contact: Dr Mark James, NIWA Christchurch

Pigment analysis is to be explored using satellite imagery ("Seawifs" available on Internet). Detailed chlorophyll analysis and dissolved organic carbon from seawater can indicate broad classes of phytoplankton.
Category 4
Contact: Dr Barry Peake, University of Otago

Pesticides on phytoplankton. The effects of herbicides and fungicides on planktonic assemblages will provide useful information for local level monitoring but not relevant for national indicators.
Category 4
Contact: Dr Carol Stewart, University of Auckland

Physical processes affecting productivity of the oceans includes the effects of tides and currents on eutrophication in estuaries, and how flow around islands and headlands affects the distribution of planktonic animals such as fish eggs and larvae. Also freshwater runoff into coastal regions and its effects on phytoplankton.
Category 3
Contact: Prof Malcolm Bowman, University of Auckland
Dr Mark James, NIWA Christchurch

Isotopic analysis of N_{15}:N_{14} ratios in water column and particulate material. Used as a tool to determine the origins of water in embayments, from ballast water and for sewage treatment.
Category 4
Contact: Dr Mark James, NIWA Christchurch

Glutamine:glutamate ratio and the amount of glutamine per unit chlorophyll a in primary producers (phytoplankton, seaweeds) vary with iron and nitrogen levels in the water column which reflect seawater contamination. Although equipment needed to detect amino acid peaks, this method shows potential as an indicator.
Category 3
Contact: Dr Alwyn Rees, University of Auckland

Introduced exotic species from ballast water may affect biodiversity of indigenous species.
Category 3
Contact: Dr John Jillett, University of Otago
Other contact: Dr Barbara Hayden, NIWA Christchurch

3.1.2 Sediments

Estuarine enrichment indicators involve measurement of six parameters and a semi-quantitative scale. The parameters include sediment ash free dry weight, total Kjeldahl nitrogen, sediment chlorophyll a (microalgal biomass) and macroalgal biomass. This is reasonably cheap and easy to measure. It uses the top 2 cm of sediment and could be extended to the open coast.
Category 2
Contact: Dr Paul Gillespie or Mr Rodney Roberts, Cawthron Institute

Dramatic substrate changes and sedimentation rates are important for all types of habitats. Substrate changes can often be mapped and monitored but may be episodic such as during storm events. The immediate effects are understood but not the recovery of habitats. The impacts of fishing (trawling and dredging) on habitats and communities is drastic.
Category 2
Contact: Dr Terry Hume, NIWA Hamilton
Dr Simon Thrush, NIWA Wellington

Change in sediment size composition is an indicator of coastal and estuarine pollution because it indicates movement of sediment to a site from other sources. It is acting as a pressure on the ecosystem. Sediment grain size is important for deposit feeders.
Category 1
Contact: Prof John Hay, University of Auckland
Dr Ken Grange, NIWA Wellington

Contaminants adhering to or in sediment can also be measured to detect heavy metal or organic contamination as a pressure on the system.
Category 1
Contact: Prof John Hay, University of Auckland

3.1.3 Margins

Dune vegetation mapping includes mapping the distribution of pingao (native sand-binding sedge) and marram grass (introduced species that smothers pingao) on sand dunes. The database goes back to the 1950s using 1:25,000 maps. In 1990s vertical aerial photography is now used plus supporting information from scientists. The team is working with regional councils in each region to produce area measurements of changes with time of dunes and vegetation types, not dune quality, although the vegetation will reflect this.
Category 2
Contact: Dr Mike Hilton, University of Otago
Dr Trevor Partridge, Landcare Lincoln
Dr Peter Johnson, Landcare Otago
Comment: This type of database could perhaps be extended to other coastal ecosystems such as mangroves as Category 3.

3.1.4 Benthic Animals

Deep reef community structure is being studied to find out the effects of long term patterns on sizes and shapes of the communities because they are relatively immune to seasonal noise. These are communities of sponges, ascidians and bryozoans that live in offshore sub-tidal waters of approximately 20 metres. It is possible that in time this research could lead to the development of these communities as indicators of the health of coastal ecosystems. The presence or absence of structurally important species e.g. gorgonian corals, or keystone species could be important indicators. There could be a hierarchy of indicators such as the effects of cyclone Bola, terrestrial changes and downstream marine changes.
Category 3
Contact: Dr Chris Battersill, Dr Dennis Gordon and Dr Lional Carter, NIWA Wellington
Ms Judi Hewitt, NIWA Hamilton

Shallow soft bottom communities can be quantified as stressed or stable by collecting and weighing samples and using Warwick's index (Abundance Biomass Comparison). Identification down to species level is not required. (This is no good for estuaries or hard shore communities.) The index could be combined with a qualitative assessment of what is there with a keystone species concept or using a reference site and comparing with that. Patchiness of species, scale and sensitivity were discussed. ABC analysis is very labour intensive. However, there is plenty of room for further discussion here. Macro-invertebrate index for soft sediments are probably not possible. There is a long term (10 year) dataset on Manakau Harbour with six sand flats that have very distinct benthic communities showing variability in the way animals behave e.g. *Macomona* can deposit or suspension feed.
Category 3
Contact: Dr Bob Wear, Victoria University
Mr Rodney Roberts, Cawthron Institute
Dr Stephanie Turner and Dr Simon Thrush, NIWA Hamilton

Shallow coastal communities are being identified by DoC around the country. It may be easier to identify key species rather than communities. A huge amount of information is available in regional councils, NIWA, museums etc. that could be pulled together by asking the right questions. An initial classification is needed.
Category 3
Contact: Dr Rob Murdock, NIWA Wellington

Suspension feeders suggested as an alternative to monitoring community structure, looking at temporal changes (effects of turbidity, toxins) and using existing information.
Category 3
Contact: Dr Conrad Pilditch, University of Waikato

Key species present or absent are good indicators of the health of the ecosystem, natural character and other human uses and values. These species may be wanted or unwanted, important in themselves or indicators of the presence of other species. For example, the presence of horse mussel beds can indicate where scallop beds may be found; both get wiped out by scallop dredges.
Category 1
Contact: Mr Rodney Roberts, Cawthron Institute
Dr Rob Murdock, NIWA Wellington

Change in species diversity for invertebrate animals may be better than an invertebrate index. Beaches and estuaries have low species numbers anyway and multivariate measures of community composition are probably better.
Category 3
Contact: Dr Keith Probert, Otago University

Shellfish "health" is important at all levels: population level (trends), physiology (cellular level), and condition of animals leading to biomarker development. Environmental variables such as bacteria levels and rainfall affecting mussel condition and growth are studied in the Marlborough Sounds
Category 3
Contact: Dr Carol Stewart, University of Auckland
Dr Mark James, NIWA Christchurch

Marine Reserves have been found to work with regard to commercial species. Research is to be broadened out to the North Island to look at the implications of protection on the general ecology of the system. Depletion from fishing affects all communities. As a wider variety of animals taken, the community structure will change. This complicates obtaining a baseline or reference site but these could be set up with iwi through taiapure.
Category 3
Contact: Dr Russ Babcock and Dr Alwyn Rees, University of Auckland
Dr Ken Grange, NIWA Nelson

Effects of antifouling paint caused serious and localised effects including on the reproductive success of a snail.
Category 4
Contact: Dr Carol Stewart, University of Auckland

Effects of metals on benthic animals are studied using condition indices for bivalves and how environmental factors affect these. Also the use of amphipods as potential indicators of effluent toxicity. Benthic animals are also sampled to assess the effects of oxidation pond effluent.
Category 3
Contact: Dr Islay Marsden, University of Canterbury

Benthic organisms as habitat formers are being studied to assess the processes and long term monitoring changes. Also the direct affects on near shore environments, damage and recovery.
Category 3
Contact: Dr Dave Schiel, University of Canterbury

Reference: Steve Cook: *Invertebrate taxonomy, ecological distribution and abundance*. Published September 1998 (will be important for regional councils).

The caution was made by the researchers consulted that benthic animal sampling was expensive.

3.1.5 Benthic Plants

Macro-algae accumulate heavy metals. Their depth distribution can be correlated with sedimentation and water clarity.
Category 3
Contact: Dr Ken Grange, NIWA Nelson
Mr Rodney Roberts, Cawthron Institute

Macro-algal blooms such as sea lettuce are triggered by seasonal patterns of freshwater runoff in estuaries and are less ephemeral than phytoplankton blooms. Studies in Otago Harbour, Tauranga Harbour and the Avon-Heathcote Estuary show heavy algal growths affect the system as a whole by causing anoxic conditions and affecting invertebrates. Water fowl are OK but waders can have a reduced food source.
Category 3
Contact: Dr John Jillett

Kelp forests are smothered and killed by sedimentation and species are affected by catastrophic changes in the near shore environment. Links are needed between physical processes and biological processes. Kelp forests could be monitored in future using photos and satellite imagery.
Category 3
Contact: Dr Dave Schiel, University of Canterbury
Dr Stephanie Turner, NIWA Hamilton

Seagrass beds are monitored from an historical perspective using aerial photos back to 1940s and related to catchment changes. Sea grasses may come and go naturally and a baseline is needed. They are very productive ecosystems.
Category 2
Contact: Dr Stephanie Turner and Dr Bill Vant NIWA Hamilton
Dr Conrad Pilditch, University of Waikato
Note: Seagrass MSc at Otago, PhD on growth.

Reference: Adams, N M. 1994 *Seaweeds of New Zealand: an illustrated* *guide*. Canterbury University Press, Christchurch (will be important for regional councils).

Mangroves are monitored as above. Remote sampling could used to determine the health of mangroves in relation to sediment loads, human development and dumping.
Category 2
Contact: Dr Stephanie Turner, NIWA Hamilton

Microalgae living on sediments could provide useful indicators.
Category 3
Contact: Dr Paul Broady, University of Canterbury

Glutamine:glutamate ratio and the amount of glutamine per unit chlorophyll a in primary producers (phytoplankton, seaweeds) vary with iron and nitrogen levels in the water column which reflect seawater contamination. Although equipment needed to detect amino acid peaks, this method shows potential as an indicator.
Category 3
Contact: Dr Alwyn Rees, University of Auckland

Protozoan groups reflect de-oxidation conditions e.g. in enclosed inlets. A more specialist application.
Category 4
Contact: Dr Mark James, NIWA Christchurch

3.1.6 Fish

Reef fish and their links with the community composition of the benthos could be important.
Category 3
Contact: Dr Chris Battersill, NIWA Wellington

Biomarkers for toxic chemicals involve work on physical (e.g. asymmetry of fins in flat fish), physiological (e.g. lesions or parasite loads) and bio-chemical (enzyme functions, stress proteins and onco-gene expression) markers of toxic chemical stress in fish species. This work will focus on species with high commercial, recreational and cultural relevance and attempt to link markers of toxic stress to reproductive potential.

In this way an indicator of stress in an individual organism can be used as an indicator of the state of the species in the ecosystem by referring to its reproductive potential and therefore the sustainability of the species.
Category 3
Contact: Dr Julie Hall, NIWA Hamilton
Dr Keith Hunter, University of Otago

3.1.7 Birds and Mammals

Species presence/abundance can be used as an indicator and can involve public knowledge, local ornithological societies and interest groups (see below). A national centre would be needed to co-ordinate the information.
Category 2
Contact: Dr Mike Hilton, Dr John Jillett and Dr Barry Peake, University of Otago

Change in species range can be a good national indicator of environmental change e.g. penguins species not North of Tairoa Head, Hooker sealion recovering range, albatross on Tairoa Head etc., no yellow-eyed penguins in Northland, Sooty shearwaters in Tasmania monitored.
Category 2
Contact: Dr Mike Hilton and Dr Henrik Moller, University of Otago

Pesticide residues in raptors can affect their reproductive success.
Category 3
Contact: Dr Paul Jones, ESR
Prof Malcolm Bowman, University of Auckland

3.2 Potential Indicators of Human Uses and Values *: Natural Character*

3.2.1 Water Column

Water clarity (as for Ecosystem Health)

3.2.2 Sediments

Dramatic substrate changes and sedimentation rates may affect natural character (see Ecosystem Health)

Changes in sediment size composition as an indicator of pollution may affect natural character (see Ecosystem Health)

Coastal erosion causing shoreline fluctuations and having significant effects on animal habitats and local communities. Study of a number of communities situated at different levels of risk through coastal erosion (Environment Waikato). In general, measurements of coastal erosion and sediment transport need to be standardised.
Category 2
Contact: Mr Jim Dahm, Environment Waikato
Dr Mike Hilton, Otago University
Dr Phil Osborne, University of Auckland

Sea level measures and wave climates are important indicators of physical change on the coastline but are not measured around New Zealand, only local records and no long term records. NIWA setting up six sea level recording sites. CRC and ARC now measuring wave climates regularly.
Category 2
Contact: Dr Bob Kirk, University of Canterbury
Dr Mike Hilton, University of Otago
Dr Terry Hume, NIWA Hamilton

3.2.3 Margins

Public access to the coast needs addressing but may not be a national issue.
Category 4
Contact: Mr Jim Dahm, Environment Waikato

Change in beach profile is related to coastal erosion (see above) and can be a risk to swimmers. Current study at Massey University.
Category 3
Contact: Dr Patrick Hesp, Massey University

Revegetation of dunes is undertaken to hide developments behind the beach and preserve natural character.
Category 4
Contact: Mr Jim Dahm, Environment Waikato

Beach litter is collected by "Beach care" groups around the country. Could be used to assess breakdown rates and currents. Debris captured from stormwater drains and related to the catchment. Virgin plastic pellets are monitored as an index of marine pollution. "Island care" involves annual cleanups of Hauraki Gulf islands.
Category 1
Contact: Dr Murray Gregory, Dr Carol Stewart and Dr Gail Arnold, University of Auckland
Dr Bob Wear, Victoria University
Mr Jim Dahm, Environment Waikato

3.2.4 Benthic Animals

Key species present or absent (see Ecosystem Health)

3.2.5 Benthic Plants

Macro-algal blooms affect the natural character of estuaries (see Ecosystem Health).

Mangroves form an important component of the natural character of the coast (see Ecosystem Health).

3.2.6 Fish

Key species present or absent (as for Benthic Animals).

3.2.7 Birds

Species presence/abundance (as for Ecosystem Health).

3.3 Potential Indicators of Human Uses and Values *: Food Gathering*

3.3.1 Water Column

Food species present or absent.
Category 1

Bacterial levels in water where food is gathered is good indicator. The techniques for measuring bacterial levels are well established although interpretation is still being researched.
Category 1
Contact: Dr Bill Vant, NIWA Hamilton

Toxic contaminants in the water column are monitored using of shellfish by the Auckland Regional Council (ARC). The ARC has also used synthetic membranes which concentrate contaminants by osmotic processes thereby reducing some of the variables inherent in using animals. There is a reasonable understanding of how to undertake this type of monitoring although it is still an area of basic research.
Category 2
Contact: Mr Chris Hatton, ARC
Dr Carol Stewart, University of Auckland

3.3.2 Sediments

Coastal erosion and sedimentation will affect food gathering (see Natural Character).

3.3.3 Margins

Public access may affect food gathering (see Natural Character).

3.3.4 Benthic Animals

Food species present or absent
Category 1

Toxic contaminants, such as the concentration of certain metals, organic compounds and bacteria, in food species such as shellfish are measured in New Zealand estuaries that are subject to contaminant inputs. Levels of contaminants that present human health risks have been established in many cases. These are therefore well established indicators of the state of the food species relative to their potential as food.
Category 1

"Mussel Watch" or "Oyster Watch" started in the US about 10 years ago using mussels and studies the concentration of contaminants (trace metals, PAHs, radioactive isotopes, pesticides), long term trends and transplant experiments. This has been implemented at Otago University using mussels and oysters and other parts on New Zealand. Cawthron Institute is involved with the US programme. NIWA Hamilton is starting to look at fish.
Category 2
Contact: Dr Barry Peake, University of Otago
Mr Geoff Mills and Dr Simon Thrush, NIWA Hamilton
Dr Bob Wear and Dr Jonathon Gardner, Victoria University
Mr Dominik McCarthy, ARC.

"Shellfish health" (see Ecosystem Health).

Mutagen and viral contamination in oysters showed a high correlation between mutagenicity and level of organochlorines at a variety of sites. Similar correlation for viral contamination.
Category 2
Contact: Prof John Hay, University of Auckland

3.3.5 Benthic Plants

Key species present or absent may affect natural character and other human uses and values. These species may be wanted or unwanted, important in themselves or indicators of the presence of other species.
Category 1

3.3.6 Fish

Key species present or absent (as above).

3.4 Potential Indicators of Human Uses and Values *: Recreation*

3.4.1 Water Column

Bacterial levels in water used for contact recreation is good indicator. The techniques for measuring bacterial levels are well established although interpretation is still being researched.
Category 1
Contact: Dr Bill Vant, NIWA Hamilton

Water clarity (see Ecosystem Health).

3.4.2 Sediments

Coastal erosion affects recreational use of the coast (see Natural Character). This can be a risk to swimmers and is studies at Massey University
Category 2
Contact: Dr Patrick Hesp, Massey University

3.4.3 Margins

Public access (see Natural Character).

Beach litter (see Natural Character).

Change in beach profile is related to coastal erosion (see Natural Character).

3.4.4 Benthic Animals

Species diversity may be an important indicator of recreational value, particularly for mud flats, estuaries and rocky shores.
Category 1

3.4.5 Benthic Plants

Seagrass beds may affect recreational use of the coast (see Ecosystem Health).

3.4.6 Birds and Mammals

Species presence/absence (see Ecosystem Health).

3.5 Potential Indicators of Human Uses and Values : *Aquaculture and Fishing*

3.5.1 Water Column

Key species present (see Natural Character).

Toxic algal blooms (see Ecosystem Health).

Bacteria levels (see Food Gathering).

3.5.2 Sediments

Coastal erosion (see Natural Character).

3.5.3 Benthic Animals

Key species present (see Natural Character).

(For other potential indicators, see Food Gathering)

3.5.4 Benthic Plants

Key species present (see Natural Character)

3.5.5 Fish

Key species present (see Natural Character).

Toxic contaminants (see Food Gathering).

Species abundance is a good indicator or commercial potential.
Category 2

3.5.6 Birds and Mammals

Key species present (see Natural Character).

4 CLASSIFICATION AND INVENTORIES OF COASTS AND ESTUARIES

Because of the complexity of the coastal environment an appropriate classification system will need to be applicable at different scales and to different levels of detail. At a broad scale, the coastal environment of New Zealand has been classified by the Department of Lands and Survey (1985) according to 3 major climatological divisions. At finer scales, Hume and Herdendorf (1988) classified New Zealand's estuaries into 16 basic types on the basis of morphology and showed how the variation in physical environments between these types had important resource management consequences. Other factors which are important from a classification point of view would be water depth, geomorphology (e.g. open coasts, estuaries harbours - all of which can be further subdivided), substrate (hard and soft shores) and the influence of ocean currents.

It appears that the need to develop classification systems for the coast depends of the complexity of the core set of indicators that are finally decided on. If the indicators that are used are simple to interpret and are very broad indicators (an example of this might be litter on beaches) complex classifications are not required. Finer resolution of coastal environments would be needed for other indicators (e.g. mussel flesh contaminant concentration interpretation would need to allow for differences in natural concentrations and other factors). Very fine scale resolution of coastal environments would be needed to interpret information about, for example, benthic community structure.

The following references to New Zealand classification systems and inventories were noted at meetings:

- Department of Conservation: *Coastal Resource Inventory*. First Order Survey. Department of Conservation, Wellington. (Separate inventory for each conservancy)

- Department of Lands and Survey (1985): *Coastal and marine ecological areas of New Zealand: a preliminary classification for conservation purposes.*

- Gibb, JG; Sheffield, AT; Foster, GA (1992): *A standardised coastal sensitivity index based on an initial framework for physical coastal hazards information.* Head Office, Department of Conservation, Wellington.

- Hume, TM and Herdendorf, CE (1988): A geomorphic classification of estuaries and its application to coastal resource management - a New Zealand example. *Ocean & Shoreline Management* ***11:*** 249-274.

- Johnson, PN (1993): Dry coastal ecosystems of New Zealand. In: E van der Maarel, (ed.) *Ecosystems of the world 2B: dry coastal ecosystems*: Elsevier.

- Tortell, P (ed.) (1981): *New Zealand atlas of coastal resources*. Government Printer, Wellington.

- Walls, K (compiler) (1995): *Draft New Zealand coastal classification system.* Department of Conservation, Wellington.

  The above reference covers a number of classification systems that have been proposed. In July 1998, NIWA are planning to assimilate the Walls (1995) records with other geological records in a 5-year programme to develop a coastal classification system.

5 CONCLUSION

The meetings held at the university and NIWA campuses around the country have resulted in a large amount of information that could be used for the development of a core set of national environmental indicators for New Zealand's coasts and estuaries.

Of the two types of indicators to be developed, the assessment of overall ecosystem health may be more difficult due to the lack of available indicators than assessment of suitability for human uses and values where the indicators are more readily available. For both types of indicators there will be a need for baselines to be set against which deviations from a regional mean, for example, may be useful in the national context.

It will be difficult to identify indicators that can be related to specific causes. However, the Pressure-State-Response system allows us to identify indicators that reflect pressures on the system such as contaminants, erosion and sedimentation, and those that reflect the current state of the system such as water clarity, shellfish health and sea grass beds. The potential indicators that have been identified in Table 1 are a combination of state and pressure indicators. No response indicators were identified.

From approximately 56 potential indicators identified, only 10 are in Category 1, "ready to use". Considerable resources will be needed to develop more of these indicators, particularly those in category 3, but some of them are already under development at NIWA and universities and these areas of research need to be monitored for results that could provide useful additions to the national set of indicators.

The potential indicators in Category 2, in which the basic research has been done, could be prioritised for their usefulness and indicators developed from these. There are 13 potential indicators in this category, and these focus on a particular need for indicators of coastal erosion, sedimentation, beach profiles, sea level measures and wave climates.

APPENDIX I:

List of Attendees at Meetings

List of Attendees at Meetings

University of Otago Meeting
22 September 1997

Name	Organisation	Area of Expertise/Interest
Dr Mike Hilton	University of Otago	Coastal geomorphology
Dr Mike Barker	University of Otago	Intertidal and subtidal ecology
Dr John Jillett	University of Otago	Marine ecology
Dr Keith Probert	University of Otago	Marine Ecology
Dr Barrie Peak	University of Otago	Marine toxicology
Ms Karen Bell	MfE	
Mr Eric Pyle	MfE	
Ms Megan Linwood	MfE	
Mr Ton Snelder	NIWA	
Dr Jonet Ward	Lincoln Environmental	

NIWA Wellington Meeting
25 September 1997

Name	Organisation	Area of Expertise/Interest
Mr Rodney Roberts	Cawthron Institute	Marine Biology and Aquaculture
Dr Ken Grange	NIWA	Marine benthic ecology
Dr Dennis Gordon	NIWA	Marine taxonomy
Dr Chris Battersill	NIWA	Marine benthic encrusting communities
Dr Rob Murdoch	NIWA	Marine biology/ecology
Dr Bob Weir	Victoria University	Plankton, crustacean benthic risk assessment environmental impact
Dr Jonathon Gardener	Victoria University	As per above
Ms Karen Bell	MfE	
Ms Megan Linwood	MfE	
Mr Ton Snelder	NIWA	
Dr Jonet Ward	Lincoln Environmental	

NIWA Hamilton Meeting
30 September 1997

Name	Organisation	Area of Expertise/Interest
Dr Stephanie Turner	NIWA	Marine ecologist
Mr Geoff Mills	NIWA	Organic contaminant chemistry
Dr Bryce Cooper	NIWA	Sediment inputs/landuse effects
Ms Judi Hewitt	NIWA	Marine ecologist/statistician
Dr Mal Green	NIWA	Sediment dynamics/physics
Dr Don Morrisey	NIWA	Marine ecologist
Dr Simon Thrush	NIWA	Marine ecology
Dr Terry Hume	NIWA	Marine geology/sediments
Dr Bill Vant	NIWA	Coastal eutrophication
Dr Conrad Pilditch	Waikato University	Marine ecology
Mr Eric Pyle	MfE	
Ms Megan Linwood	MfE	
Mr Ton Snelder	NIWA	
Dr Jonet Ward	Lincoln Environmental	

Also meetings with Mr Jim Dahm (Environment Waikato) and Dr Julie Hall (NIWA Hamilton) on 30 September, 1997

University of Auckland Meeting
1 October 1997

Name	Organisation	Area of Expertise/Interest
Prof John Hay	University of Auckland	Air Quality, Climate Change, Coastal Management
Dr Alwyn Rees	University of Akl	Nitrogen metabolism in Algae (Phytoplankton and seaweeds)
Dr Phil Osborne	University of Akl	Coastal and Marine processes, sediment dynamics
Prof Malcolm Bowman	University of Akl	Coastal and estuarine oceanography, ocean modelling remote sensing, fisheries science.
Dr Carol Stewart	University of Akl	Coastal marine contaminants, bio-monitoring
Ms Megan Linwood	MfE	
Mr Ton Snelder	NIWA	
Dr Jonet Ward	Lincoln Environmental	

University of Canterbury Meeting
2 October 1997

Name	Organisation	Area of Expertise/Interest
Dr Martin Single	University of Canterbury	Coastal processes, geomorphology and management
Dr Bob Kirk	University of Canty	Coastal processes, landforms and coastal management
Dr Colin McLay	University of Canty	Crustacean Ecology and Systematics
Dr Islay Marsden	University of Canty	Shellfish eco-physiology, toxicology, estuarine ecology
Dr Mark James	NIWA	Macro-invertebrate and Plankton Ecology
Dr David Schiel	University of Canty	Marine Ecology, aquaculture fisheries
Ms Megan Linwood	MfE	
Mr Ton Snelder	Niwa Christchurch	
Dr Jonet Ward	Lincoln Environmental	

Table 1: Framework for issues and potential indicators of coastal and estuarine environments raised in meetings

Environmental Component	**Potential Indicators of:**				
	Ecosystem health	**Human uses and values**			
		Natural character	**Food gathering**	**Recreation**	**Aquaculture & fishing**
Water column	• Oxygen[1] • Water clarity[1] • Phytoplankton[1,4] • Toxic algal blooms[1] • Planktonic assemblages[4] • Pigment analysis[4] • Pesticides on phytoplankton[4] • Physical process affecting productivity[3] • Isotopic analysis[4] • Glutamine:glutamate ratio[3] • Introduced exotic sp[3]	• Water clarity[1]	• Food sp present[1] • Bacteria levels[1] • Toxic contaminants[2]	• Bacteria levels[1] • Water clarity[1]	• Key sp present[1] • Toxic algal blooms[1] • Bacteria levels[1]
Sediments	• Estuarine enrichment indicators[2] • Dramatic substrate changes and sedimentation rates[2] • Sediment size[1] • Contaminants[1]	• Dramatic substrate changes and sedimentation rates[2] • Sediment size[1] • Coastal erosion[2] • Sea level measures and wave climates[2]	• Coastal erosion and sedimentation[2]	• Coastal erosion[2]	• Coastal erosion[2]
Margins	• Dune veg. mapping[2]	• Public access[4] • Beach profile[2] • Reveg of dunes[4] • Beach litter[1]	• Public access[4]	• Public access[4] • Beach litter[1] • Change in beach profile[2]	
Benthic animals	• Deep reef community[3] • Shallow soft bottom communities[3] • Shallow coastal communities[3] • Suspension feeders[3] • Key species present[1] • Species diversity[3] • "Shellfish health"[3] • Marine reserves[3] • Effects of antifouling[4] • Effects of metals[3] • Habitat formers[3]	• Key species present[1]	• Food sp present[1] • Toxic contaminants[1] • "Mussel/oyster watch"[2] • "Shellfish health"[3] • Mutagens & viruses[2]	• Species diversity[1]	• Key sp present[1] • Toxic contaminants[1] • "Mussel/oyster watch"[2] • "Shellfish health"[3] • Mutagens & viruses[2]
Benthic plants	• Macro-algae[3] • Macro-algal blooms[3] • Kelp forests[3] • Seagrass beds[2] • Mangroves[2] • Micro-algae[3] • Glutamine:glutamate ratio[3] • Protozoan groups[4]	• Key species present[1] • Macro-algal blooms[3] • Mangroves[2]	• Key species present[1]	• Sea grass beds[2]	• Key sp present[1]
Fish	• Reef fish[3] • Biomarkers for toxic contaminants[3]	• Key species present[1]	• Key species present[1]		• Key sp present[1] • Toxic contaminants[1] • Species abundance[2]
Birds, mammals	• Species presence/abundance[2] • Change in sp range[2] • Pesticide residues in raptors[3]	• Species presence/abundance[2]		• Species presence/ abundance[2]	• Key sp present[1]

Categories suggested for indictors:

[1] Ready to use now as an indicator
[2] Basic research has been done from which an indicator can be developed
[3] Promising as an indicator but more fundamental research is required
[4] Not worth pursuing as an indicator because of lack of relevance to the National Environmental Performance Indicators Programme