National SCIENCE Challenges

SUSTAINABLE SEAS

Ko ngā moana whakauka

Assessing present health

Guidance

What is the present ecological health of the area?

This question comes up in meetings with community groups, environmental lawyers and parliamentarians. Many have observed changes and may have ideas on why but are not sure how to put these in a framework that will be taken seriously by councils, businesses, industry or government. This document sets out general principles for how key changes in ecological indicators in a consistent direction over time can be used as important indicators of shifts in ecological health. These changes can be measured by quantitative monitoring over time but can also be estimated from local observations. We provide two levels of methods – those that can most easily be used by non-scientists (black text), and others that are more technical for council or government scientists (blue text). Towards the end of this document we summarise other indicators presently used in Aotearoa New Zealand along with who can be contacted for more information.

As most of Aotearoa New Zealand's marine species are not in poor health, the document focuses on indicators that separate medium to good health. However, there are some strong signals of poor ecological health. These include fish kills, hypoxia, algal blooms, persistent brown coloured waters (high turbidity), the absence of shellfish or kelp and muddy sediments lying on a base of sand or rock (indicating that the sediment load is larger than the capacity of the system to cope with the load and self-clean). When these indicators are present the system is in a very poor state with slow recovery potential at best.

The difficulty with indicators is that we have a massive diversity of estuary and coastal types in Aotearoa New Zealand, ranging from fiords to large shallow barrier lagoon systems, large embayments and open coasts. How indicators manifest is linked to the specific context of where we are looking. Ecological health does not always change in a simple linear fashion, sudden large changes (tipping points) are increasingly occurring under the cumulative effects of multiple different human activities. Because poor health is linked to slow recovery, we need to look for signals ahead of the catastrophes. Challenge research has not only summarised some warning signals (Thrush et al 2016, Hewitt et al 2019), but the ecological indicators detailed below are those that specifically relate to how the ecosystem responds to stress, how likely a sudden change is and how slow recovery may be. Guidance to scientists on how to estimate resilience to change and how it affects risks associated with adaptive management or managing to recovery is available (An ecological principles-based approach to guide coastal environmental management).

Ecological indicators and associated principles

These indicators and principles are related to how the ecosystem responds to change/stress. Note that when numbered the numbering is the same as in Gladstone-Gallagher et al (2024).

Have the 'slow' to regrow structural habitats been lost? (Ecological status indicator 1)
Areas should contain multiple long-lived biogenic habitats. These may be provided by long-lived species, such as horse mussels, sponges, bryozoans, and rhodoliths, or the habitat itself may be long-lived, such as dense beds of oysters, mussels, cockles, pipi and wedge shells, tube worm mats, and vegetated habitats (mangroves, seagrass, crustose algae, or different types of seaweeds). Decreasing number of habitat types, decreasing coverage or replacement of habitats created by long-lived species with shorter-lived species (for example, replacement of kelp with urchin barrens) are generally indicative of anthropogenic stressors and decreasing health.

Many councils already have some mapping information on these as part of regional monitoring that could be used for estimating change, but mātauranga and local knowledge can often be more complete.

The potential overall coverage for the area can be estimated from environmental data by the Ecosystem Services Principles method (Townsend et al 2011, for examples see *Measuring ecosystem services and assessing impacts*) and then compared with the observed coverage. A method that requires more technology and sampling is provided by the use of drones, drop cams and machine learning (Schenone et al 2022). For seagrass, satellite images can be used (Shao et al 2024). When there is sufficient information coupled with environmental data, species distributions modelling can be useful (Rullens et al 2021).

Is the seascape diversity of biogenic habitat types high? (Ecological status indicator 5)
These habitat types include more than the long-lived ones mentioned above. Many mobile species also form habitats, for example snails, large crustaceans (crabs and shrimps), urchins, starfish and sea cucumbers. Collectively they provide many important functions and services, including oxygenating the seafloor sediments, processing nutrients, and providing food for other species. The more diverse types there are, the more likely that these functions can be maintained. Decreasing number of habitat types, or decreasing coverage are generally indicative of anthropogenic stressors and decreasing health.

Only rarely is information on these habitats available due to their mobility. We suggest that creating an exhaustive list is not necessary but a list that includes the common ones and any covering large areas, even if they are unique, is useful. It's also important to record the relative area covered by these habitats, to know if one habitat covers most of the area with the rest being small or occurring in one place only. This list with relative cover information can form the basis for assessing changes to these habitats (Hillman et al 2018).

Going further down a quantitative mapping route, methods to map these include a method for intertidal areas developed by NIWA for WRC (Needham et al 2014).

For species whose juveniles and adults live in the same place, is there a full range of sizes?
Not all species have juveniles and adults that live in the same place. For example, juvenile pipi live in upper estuary, mid to low tide muddy sand environments, while adults prefer very low tide to shallow subtidal high current areas. But for species whose juveniles and adults do live in the same places, size is important. It is an indicator of the robustness of the species population. If adult size is decreasing, or if adults are no longer found, the population is at risk. If small juveniles are no longer observed, then even though adults remain, the population is unlikely to be maintained as the adults reach old age and die.

Because few monitoring programmes record size of individuals, with the exception of some shellfish sizing, the best source of information is likely to be mātauranga and local experiences.

The status of the ecological network structure defined by the number and type of feedback loops (Ecological status indicator 2)
There is no easy way to measure these. However, monitoring abundance over time of species that we know facilitate other species (for example species considered in *Ecological status indicator 1*), or form groups that have been shown to contribute to other ecosystem components is a good start. Groups include large bioturbating deposit feeders (particularly *Macomona liliana* and *Macroclymenella stewartnesis*), suspension-feeding shellfish (particularly *Austrovenus stutchburyi*), and microphytobenthos (estimated by sediment chlorophyll a). All of these are groups included in the Parliamentary Commissioner for the Environment Estuaries Bayesian network model (Bulmer et al 2019, presently being extended by the Challenge in conjunction with the Ministry for the Environment (MfE)) as intermediatory components related to functions and biodiversity. Many of the species also form part of the Benthic Health models and some inform the traits-based index (see *Other indicators of health presently used in New Zealand* section further down).

Are ecological processes that regulate ecosystem resilience present? (Ecological status indicator 3)
There is no complete list of ecological processes that contribute to ecosystem resilience, however, denitrification, binding of sediments, water filtration, trophic interactions (for example predator-prey interactions), ecological connectivity, and facilitatory species interactions are all examples. Because there is no complete list, assessments of health based on this indicator should probably be confined to whether decreases over time in any of these processes can be detected.

Some of these processes are able to be estimated by Ecosystem Services Principles, integrated with environmental variables (eg denitrification can be predicted from environmental variables – see *Denitrification potential: Whitford estuary*). This approach can be refined using measurements of fluxes and the mapping of sediment habitat features using drones, dropcams and machine learning (Schenone et al 2022). Binding of sediments can be approximated by the abundance of sediment stabilising species, and water filtration by the abundance of suspension feeders.

Other indicators of health presently used in Aotearoa New Zealand

If these other indicators of health are to be used, they should be supplemented by at least some of the ecological indicators listed above as those indicators are more directly relatable to risk of further degradation, the potential for recovery and possible management actions (see *Assessing risk to management strategies*).

- **Traits-based index.** This index, constructed from the richness of macrofaunal taxa in seven functional groups, was designed to indicate functional redundancy and potential resilience to anthropogenic change (Rodil et al 2013, Berthelson et al 2018). It was developed by NIWA and Auckland Council for estuaries, has been used to analyse many estuarine monitoring programmes, and has recently been tested in subtidal areas. More information can be sought from Drew Lohrer, NIWA (drew.lohrer@niwa.co.nz).
- **Benthic Health Model index for mud and stormwater contaminants.** These two indicators were developed from regional council estuarine monitoring of intertidal soft-sediment communities (Clark et al 2019). They are used in an on-going basis by councils nationally to monitor change in their estuaries. More information can be sought from Dana Clark, Cawthron (dana.clark@cawthron.org.nz) or Judi Hewitt, University of Auckland (judi.hewitt@auckland.ac.nz)
- **Estuarine Trophic Index.** This was developed to assist regional councils in determining the susceptibility of an estuary to eutrophication, assess its current trophic state, and assess how changes to nutrient load limits may alter its current state. More information can be found at *ETI Tool 1: Determining susceptibility of estuaries to eutrophication* including links to two other tools in the set.
- **Number or area covered by invasive species.** The presence of invasive species is generally considered to represent a stressor on an area, with the more invasive species present, the lower the health. A list of these is available from the *Marine Invasive Taxonomic Service*. It is also important to know the abundance and size of the species as some small species have been living in New Zealand for many years without dramatically changing the health of areas (for example *Theora lubrica* is a small sediment dwelling bivalve which appeared in 1972).
- **Number of threatened or endangered species present.** This is one of the indicators used by Statistics NZ and MfE to track environmental change in Aotearoa New Zealand. A list of the species in each category is available from the Department of Conservation (DOC).
- **Functional integrity index.** Ecological integrity is an overarching concept that integrates multiple properties of ecosystems, including structure, function, and resilience to external change. The functional integrity index was developed for DOC to simplify the ecological integrity by targeting functional components and functional diversity of benthic communities (de Juan et al 2015) with the aim of monitoring change over time in coastal and deep-sea areas. More information is available from Jordi Tablada and *Functional traits as indicators of ecological integrity*).
- **Benthic Quality Index (BQI) for suspended sediment.** BQI's are used internationally to monitor change in marine soft-sediments, based on sensitivity to various human-related stressors. Biological traits that reflect sensitivity to suspended sediment were used to create the sensitivity scores that are then used in the standard calculations of the BQI. They are applicable to coastal (Hewitt et al 2022) and deep-sea areas (Hewitt et al 2018). More information is available from Judi Hewitt, University of Auckland (judi.hewitt@auckland.ac.nz).

Definitions

Ecological resilience is the capacity of the ecosystem to respond to change and self-regulate.

Denitrification is a process, occurring primarily in sediments, that removes excess nutrients which can generate algal blooms and hypoxia).

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