Roadmaps to EBM

National Science Challenges | SUSTAINABLE SEAS | Ko ngā moana whakauka

How do we assess the present ecological integrity of an area?

For regional council scientists

Ecological Integrity (EI) is a useful concept that seeks to capture the complex nature of ecosystems and their interaction with social wellbeing. There are numerous definitions for EI but, in general terms, it is a holistic term that seeks to capture our sense of nature, its functionality and self-organising capacity (Tett et al 2013). In fact, it is perhaps better understood by its absence rather than its presence and a challenge remains to measure EI and translate scientific terminology into operational language to inform society. Here we summarise an approach partially funded by the Challenge and collaborated on by researchers from Spain and Chile (de Juan et al 2018). The approach uses a bottom-up structure that identifies, based on expert knowledge, biological components related with past and present changing conditions. We link this to ecological status indicators derived by Gladstone-Gallagher et al (2024).

De Juan et al (2018) have an initial step that involves delimiting the area of interest by defining boundaries based on geophysical (eg estuary), human activities (eg, fishing grounds), or ecological components. The Challenge recommends defining management areas based on ecological scale. Even if the management area has already been defined, it would be useful to determine the relationship between the unit size and ecological connectivity by using the *Spatial scaling decision tree* tool (see *Roadmaps to EBM: How do we decide what our management units are?*).

De Juan et al (2018)'s next two steps involve identifying existing data in the area that could be used to calculate variables representing EI, and from that use expert judgement to identify the minimum set of variables necessary to define it. In the latter step it would also be appropriate for the experts to consider how to relate each variable with a state that reflects a certain degree of increasing/decreasing EI. The Challenge has used ecological theory as expert judgment to select a number of variables that together support EI.

These variables (using the terminology/numbering in Gladstone-Gallagher et al 2024) are:

Ecological status indicator 1: The status of 'slow' to regenerate ecosystem habitat/structural components has been lost. Management areas should contain multiple 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 pipis and wedge shells, tube worm mats, and vegetated habitats (seagrass, crustose algae, or different types of seaweeds). Many councils already have some mapping information on these as part of REMP monitoring.

Areas that are mainly without biogenic habitats (eg mudflats in estuaries, shelly areas in nearshore areas that are not beaches, replacement of kelp with urchin barrens) are generally indicative of anthropogenic stressors. The potential 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 also be useful (Rullens et al 2021).

Ecological status indicator 3: The status of ecological processes (eg nutrient removal, oxygen production) that regulate ecosystem resilience are present. Some of these processes are able to be estimated by Ecosystem Services Principles, for example nitrogen removal can be predicted from environmental variables (see Denitrification potential: Whitford estuary). This approach can be refined by empirical measurements and the mapping of sediment habitat features using drones, dropcams and machine learning (Schenone et al 2022). Multiple trophic levels are also an indicator of enhanced resilience, with predators, herbivores, detritivores and omnivores all working together to stabilise foodwebs.

Ecological status indicator 5: The seascape diversity of biogenic habitat types. These habitat types include more than the long-lived ones mentioned above, for example high density areas of more mobile species (snails (including mud snails), large crustaceans (crabs and shrimps), urchins, starfish, sea cucumbers). An exhaustive list is not necessary, but should include the common ones and any covering large areas, even if they are unique. It's also important to record the relative area covered by these habitats, just to know if one habitat covers most of the area with the rest being small or occurring in one place only. This information can also be useful to track changes over time (Hillman et al 2018). Going further down a quantitative mapping route, methods to map these include those developed for intertidal by NIWA for Wellington Regional Council (Needham et al 2014).

For species whose juveniles and adults live in the same place, is there a full size range of individuals? Locals will often know whether sizes have changed over time, or whether juveniles or adults are no longer found.

Ecological status indicator 2: The status of the network complexity – the number and types of feedback loops. This final indicator is the hardest to measure as it is based on the connections between ecosystem components (sediment physical and chemical characteristics, macrofaunal and floral species, common fish species and diversity, and common bird species and diversity). If data is available on at least some of these an interaction network can be constructed based on expert opinion and the network tested for its validity using Structural Equation Modelling (Thrush et al 2021). Otherwise for some stressors (such as mud content, sedimentation rate, suspended sediment and ammonium porewater concentrations), threshold responses to them can be used to infer likely complexity and feedbacks.

A final step is to integrate all the variables together, either directly by for example multi-variate analysis, or by using weights to transform the data and applying multi-criteria analysis (de Juan et al 2018).

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