National Science Challenges
SUSTAINABLE SEAS
Ko ngā moana whakauka



# 5 How to incorporate risk and uncertainty in ecosystem-based management

**For our seas to thrive, people need to make decisions about managing marine ecosystems in a holistic, inclusive way – this is ecosystem-based management. These decisions involve assessing risk from different points of view and dealing with uncertainty and must acknowledge our obligations under a Te Tiriti o Waitangi partnership. This guide explains what an ecosystem-based risk assessment should be able to do and provides a decision tree to help you choose the right method.**

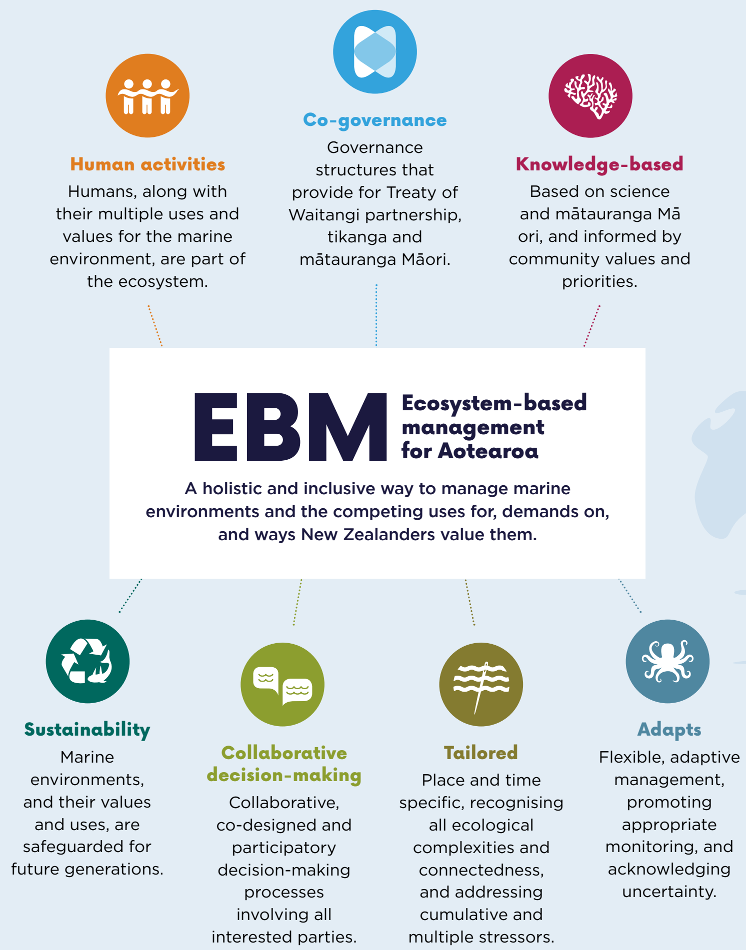
Previous guides in this series, based on Sustainable Seas National Science Challenge research, explain why it's important to understand the worldviews, experiences, and context of all people involved in marine management, and to have good practices for including them all. Use this knowledge of all perspectives to make decisions on the right risk assessment method or methods for your circumstances.

## What should an ecosystem-based management (EBM) risk assessment be able to do?

Many of the risk assessment methods used in Aotearoa New Zealand and internationally are not suitable for ecosystem-based marine management. Most methods are framed around minimising degradation and loss, rather than assessing ecosystem health recovery options.

To help find a suitable method, consider the six assessment criteria on the following page. These criteria are based on the ecosystem-based management principles shown here.

In any situation, you may not need to deal with all the considerations below. But if you use a method that can cover all these considerations, it shows your process is theoretically able to cover all considerations, and that if you've left interests, stressors, and values out of the risk assessment process, you have done this deliberately.



## EBM risk assessment criteria

### 1. Does the method integrate ecosystem complexity?

**Does it assess risk to multiple ecosystem components?**

- Physical disturbance
- Multiple species removal and effects on benthic habitats
- Changes to trophic levels, productivity, and size of important species
- Alteration of food quantity and quality
- Species addition, for example invasive species)
- Biodiversity loss
- Contamination, including behavioural changes and toxicity
- Changes to ecosystem function, for example movement and connectivity, biological traits, chemical balances and elemental cycles

**Does it assess indirect effects, interactions, feedbacks, and non-linear responses?**

Ecological responses to stress are often non-linear, particularly those arising from the cumulative effects of multiple stressors, and they involve indirect effects and feedbacks. Interactions between different stressors or different ecosystem components also may occur.

**EBM principles supported:**

### 2. Does the method accommodate a range of components, outcomes, and stressors?

As well as assessing the ecological response of multiple ecosystem components, a risk assessment method should incorporate social, cultural, and economic values and activities that will be affected by or drive ecosystem responses. Examples of cultural outcomes include cultural health indices and the **Mauri Compass**.

**EBM principles supported:**

### 3. Does the method assess risk at a specific place and time?

The relative importance of different ecosystem components, processes, and their connections differ with place and time, as do the disturbance or stressor regimes that affect them. Outputs that communicate the risk posed to the location of interest, for example maps, and how this risk varies through time, are important.

**EBM principles supported:**

### 4. Does the method accommodate different knowledge types?

Data from multiple knowledge types is essential to fill quantitative data gaps, widen the evidence-base, and ensure that ecosystem-based management objectives align with the values of multiple sectors of society. Examples of knowledge types include expert opinion, mātauranga Māori, local knowledge, and quantitative data.

While 'best available information' has often been seen as numeric (quantitative), decisionmakers, and the courts on review, frequently consider a range of considerations beyond numerical data and models. Mauri is an example of mātauranga Māori being taken into account in decision making — under **Te Mana o Te Wai**.

**EBM principles supported:**

### 5. Does the method evaluate recovery as well as degradation?

Risk assessment methods must be able to evaluate recovery explicitly and separately, rather than combining it with impact. Ecological feedbacks can create recovery lags that hinder recovery, even when stressors are reduced. The object of the risk assessment may be recovery of the mauri or ecosystem health rather than minimising future degradation.

**EBM principles supported:**

### 6. Does the method evaluate and communicate uncertainty

Generally, uncertainty is explored through scenarios that evaluate the relative success of different actions. While uncertainty can be difficult to separate from risk, in a risk assessment method that's being used for decision making, uncertainty can be a highly important part.

Uncertainty can be used to make explicit the frequently voiced 'we don't know enough to make a decision' and test whether more information would actually be helpful or whether this lack of knowledge is being used as a delaying tactic.

Uncertainty can also help with transparency in decision making by making explicit how likely different actions are to achieve the desired response — whether it be environmental improvement or minimising degradation.

**EBM principles supported:**

## A decision tree to help choose a risk assessment method

This decision tree can help you choose a risk assessment method in Aotearoa New Zealand. You can find a full assessment of these methods in Clark et al. (2021) and Inglis et al. (2018). You can read about potential gaps and methods still in development in our full research document on the **Sustainable Seas website**.

We've used symbols to distinguish additional output types: Spatial, Temporal, Scenario, Uncertainty

We've used colours to show tool outputs as **easy**, **moderate**, or **hard**. Table 1 on the following page has definitions for the column headings in the decision tree.

Some tools are more flexible and can perform over a wider range of conditions. For example, Bayesian Networks or Likelihood-Consequence models can be used for risk assessments that focus on a single stressor, single response, for reporting on a single component (not ecosystem-based management). They can also be used for multiple stressors, multiple component, and multiple discipline risk assessments (ecosystem-based management).

Other methods have more specific applications, for example, SEFRA, which to date has only been used to assess the risk of fishing to endangered or vulnerable species.

As well as the considerations outlined in the decision tree, a complex, and difficult to quantify or summarise, interplay exists between the precision, accuracy, and uncertainty in outputs from different risk assessment methods. For more information about this, read the full research document on our **website**.

| Complexity | Knowledge type | Information requirements | Outcomes | Time/cost to implement | Approach | Outputs and interpretability |
|---|---|---|---|---|---|---|
| Low | Qualitative | Low | Medium | Low | **SICA** – Scale-Intensity Consequence Analysis | easy |
| Low | Multiple | Medium | Medium | Medium | **PSA** – Productivity Susceptibility Analysis | easy |
| Medium | Multiple | Low | Low | Low | **LC** – Likelihood-Consequence | easy |
| Medium | Quantitative | Medium | Medium | High | **SEFRA** – Spatially Explicit Fisheries Risk Assessment | Spatial, Uncertainty (moderate) |
| Medium | Quantitative | High | Medium | Medium | **SAFE** – Sustainability Assessment for Fishing Effects | Uncertainty (moderate) |
| Medium | Quantitative | High | Medium | High | **ERFA** – Ecological Response Footprint Analysis | Scenario, Spatial, Temporal (easy) |
| High | Qualitative | Medium | High | Medium | **System Mapping** – Qualitative Network Models or 'Loop analysis' | Temporal (moderate–hard) |
| High | Multiple | Low | Medium | Medium/High | **Agent based models** – Dynamic interacting rule-based models | Scenario, Spatial, Temporal (easy–moderate) |
| High | Quantitative | High | High | Medium | **CE models** – Cumulative Effect models using generalised linear models | Uncertainty (hard) |
| High | Quantitative | High | High | High | **MSE** – Management Strategy Evaluation | Scenario, Uncertainty, Temporal (moderate) |
| High | Quantitative | High | High | High | **MDP** – Markov Decision Processes | Scenario, Temporal (moderate) |
| Very high | Multiple | Low | High | Medium | **CE principles** – Cumulative Effect principles | Scenario, Spatial, Temporal (easy) |
| Very high | Multiple | Low | High | Medium/High | **BN** – Bayesian Network | Scenario, Spatial, Uncertainty (easy) |
| Very high | Quantitative | High | High | (Very) High | **Atlantis** – Ecosystem model (biophysical, social and economic data) | Temporal, Scenario, Spatial, Uncertainty (hard) |

*Table 1: Definitions of decision tree considerations (column headings)*

| Considerations | Definitions |
|---|---|
| **Complexity** | **System complexity; number of stressors, response variables, etc.** |
| Low (‡) | Single stressor, single response |
| Medium | Multiple stressors or responses, no interactions or feedbacks |
| High | Multiple stressors or responses, interactions, indirect effects |
| Very high | Multiple stressors and components, feedbacks, interactions, indirect effects |
| **Knowledge type** | **Type of knowledge that can be used** |
| Quantitative | Numerical values |
| Qualitative | Descriptive data, eg expert opinion, principles, social surveys |
| Mātauranga Māori | Māori knowledge – the body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices. |
| Multiple | A combination of knowledge types (mātauranga Māori and at least one of: quantitative and qualitative data; semi-quantitative) |
| **Information requirements** | **Amount of available information** |
| Low | Not much information exists or is available, limited knowledge of system or case-study area |
| Medium | Some information or knowledge of the system/study area exists, including eg local knowledge, (limited) monitoring data or data from experimental studies, not location specific/for all components |
| High | An abundance of information exists to work with, including extensive spatial or temporal survey/monitoring data, spatial data layers at high resolution, local knowledge and/or mātauranga. |
| **Outcomes** | **Number and types of components included (ecological, social, economic, cultural etc.)** |
| Low (‡) | Single component (1). One type of value |
| Medium | Multiple components (3–4). One type of value |
| High | Multiple components (3–4). Multiple types of values |
| **Time/cost to implement** | **Ease of implementation, cost or time, expertise required** |
| Low | Simple method, low cost and time (eg within a week), low expertise/skill required |
| Medium | Moderate time/effort to implement the method (eg weeks-months), some expertise/skill required |
| High | Expensive or time consuming, needing specialists |
| ***Interpretability** | **Easy of interpretation of risk assessment outputs** |
| 🟢 Easy | Understood by a lay person |
| 🟠 Moderate | Understood by a lay person if the outputs are explained |
| 🔴 Hard | Expert/technical knowledge required to understand the outputs |

## What's next?

**Curious to read more detail about our research on perceptions of risk and uncertainty and communicating risk and uncertainty, read the full research document on the Sustainable Seas website.**