National SCIENCE Challenges

SUSTAINABLE SEAS

Ko ngā moana whakauka

Monitoring for tipping points in the marine environment

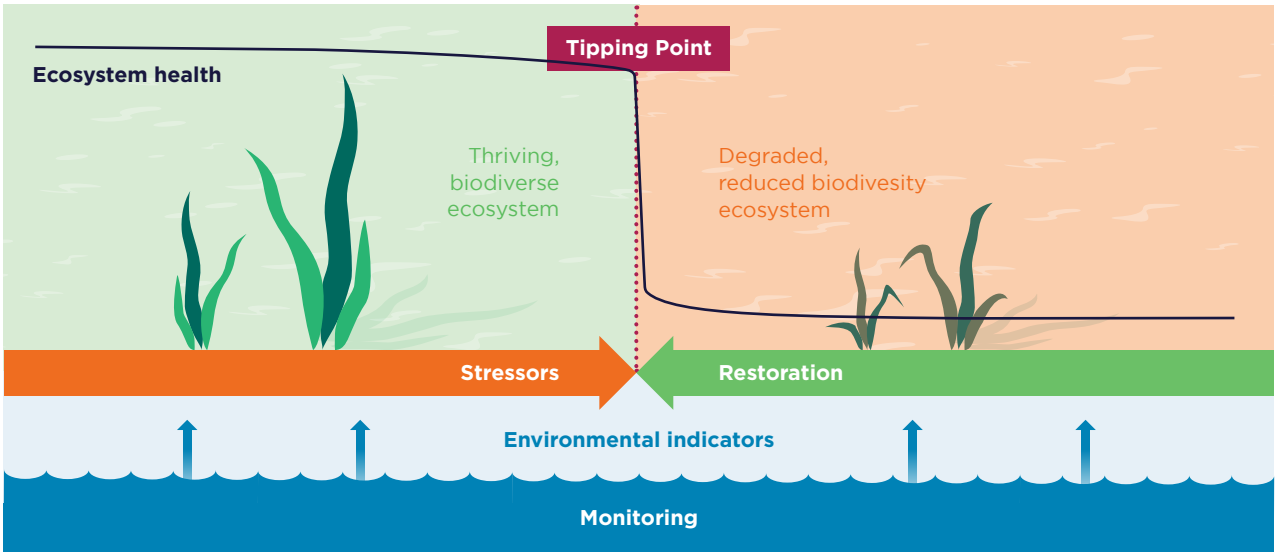
Guidance

Stressors caused by human and natural activities can lead to a 'tipping point', where an ecosystem loses its capacity to cope with change and it rapidly transforms. Tipping points are difficult to predict and often result in the loss of valuable marine resources or ecosystem services.

Environmental monitoring is critical to detect changes so that we know the **early warning signs (EWS)** of when a **tipping point (TP)** is being approached, and to increase the certainty that a TP has occurred.

- Small-scale fluctuations in the ecosystem over time and space are EWS.
- Medium- to long-term changes over time can confirm that a TP has occurred.

Monitoring to detect EWS and TP



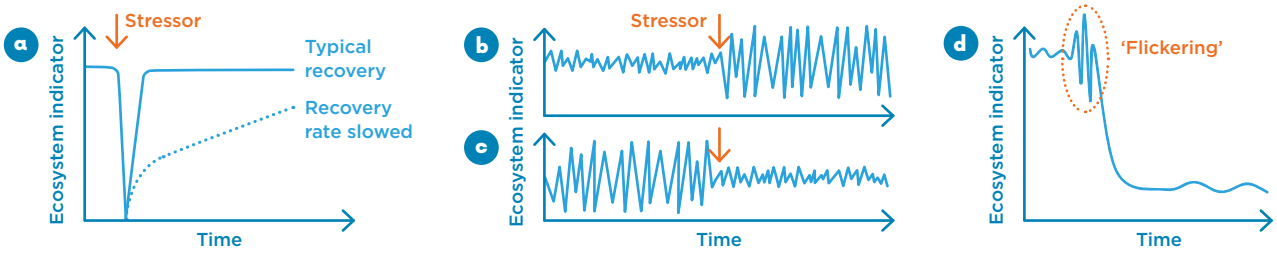
Interactions between multiple stressors can lead to a loss of ecosystem resilience and an increased risk of crossing a TP.

EWS that may indicate an upcoming TP include ecosystem indicators that:

- Have slowing rates of recovery in the ecosystem, either directly measured (diagram a) or indicated by a change in variance*, eg large variance suddenly gets smaller (diagram b) or a small variance suddenly get larger (diagram c).
- Are 'flickering' between alternate states causing increasing variance (diagram d).

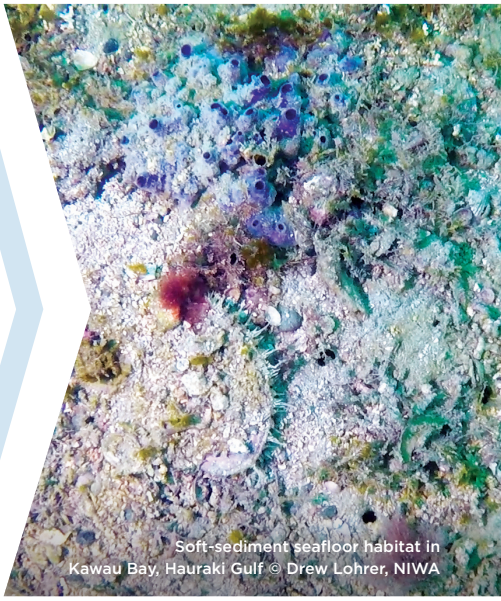
The design of monitoring programmes must be sufficiently robust to differentiate EWS and TP from natural cycles that may have an impact on marine ecosystems eg El Niño/El Niña climate cycles.

**Variance is a statistical term that measures how far a set of numbers are spread out from their average value.*



Considerations when designing monitoring programmes

- **Length of time series:** A time series of at least 15 years is necessary to take into account natural cyclic patterns eg global climate cycles.
- **Frequency of sampling (for EWS) and number of data points (for TP):** Time series with greater than 50 data points are ideal to detect a TP; within-year sampling is preferred to detect EWS.
- **Expert ecological knowledge:** Using existing ecological or local knowledge of what is expected to happen can increase your ability to detect change.
- **Covariables:** Measuring additional variables that might also cause change or confound variations over time, eg climatic indices, can also be included in your analysis.
- **Reference time series:** You can increase confidence in your ability to detect EWS and TP by comparing findings with other, longer 'reference' time series.



Soft-sediment seafloor habitat in Kawau Bay, Hauraki Gulf © Drew Lohrer, NIWA

Recommendations for robust monitoring programmes

EARLY WARNING SIGNS (EWS)	TIPPING POINTS (TP)	CONFIDENCE
A time series of at least 15 years with within-year sampling, either in space or time *OR* A time series of less than 15 years with within-year sampling either in space or time *AND* additional information (eg expert knowledge, covariables or reference timeseries) to improve the detection of variation	A time series of at least 15 years (preferably 20 years) with more than 50 data points over time	High ability to detect EWS/TP

If this recommended data is not available your ability to detect EWS and/or TP will be compromised:

EARLY WARNING SIGNS (EWS)	TIPPING POINTS (TP)	CONFIDENCE
A time series of at least 15 years but with a sampling frequency to allow for analysis with a 10-year or 5-year sliding window* • Restricted ability to detect change in variation due to the number of indicators that can be detected	A time series is at least 15 years but with only 10 – 29 or 29 – 50 data points over time • Only large or moderate changes can be detected, respectively. Additional information can be used to improve confidence	Moderate ability to detect EWS/TP
A time series of less than 15 years *OR* A time series of at least 15 years but the sampling frequency is insufficient to allow for a sliding window* of 5 years or greater	A time series is less than 15 years *OR* A time series of at least 15 years in duration but with fewer than 10 data points *AND* no additional information to improve confidence	Poor ability to detect EWS/TP

**Where a 'window' of specified length moves over the data, sample by sample, and the statistic is computed over the data in that window.*


Mussels beds at Tonga Island © Alex Connolly


Kelp and kina off the Dunedin coast © NIWA

What is required to implement these recommendations in New Zealand?

A focus on responses, not stressors

When monitoring and managing for a tipping point it is important to consider how the ecosystem is connected, focusing not just on stressors, but on the networks of ecological responses and relationships. These can act as EWS and may allow for successful remedial action.

Integration of expert ecological knowledge in monitoring design and analysis

Using expert ecological knowledge in the design and analysis of time-series monitoring programmes for tipping points is essential where only short-term or infrequent datasets are available. This can increase the certainty that a TP has occurred and is particularly relevant in New Zealand where within-year sampling in marine monitoring programmes is limited.

An increase sampling frequency where possible

The sampling duration and frequency of many New Zealand marine monitoring programmes are currently inadequate to detect EWS/TP. Where there are numerous monitoring sites, resource limitations limit the ability to perform within-year sampling across all sites. Where possible, within-year sampling should be performed in at least a proportion of sites to enhance the ability to detect EWS/TP.

Academic Publication

Hewitt JE, Thrush SF. Monitoring for tipping points in the marine environment. J Environ Manage. 2019;234:131–137

John Dory cruising Northern Arch © Crispin Middleton, NIWA

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