Using the Seafloor Disturbance Model to understand the dynamics of seafloor disturbance and recovery

Summary

A healthy, functioning marine ecosystem (see figure 1) relies on people making informed decisions about interventions to reverse the degradation of seafloor habitats.

This document introduces a modelling tool that can help you explore the effectiveness of different ways of managing stressors on seafloor habitats.

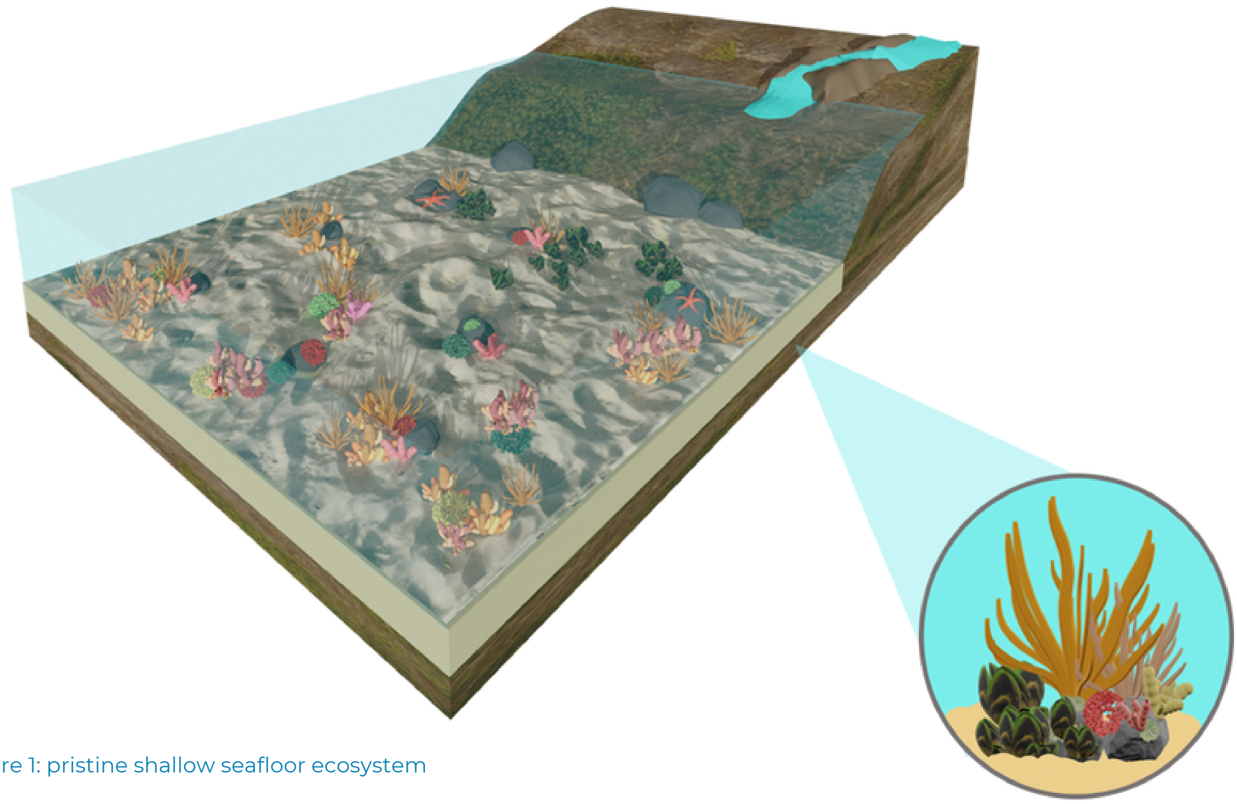


Figure 1: pristine shallow seafloor ecosystem

Modelling ecosystem responses to different interventions

The Seafloor Disturbance Model shows how an ecosystem would likely respond to different ways of managing two common coastal stressors — sedimentation and the impacts of fishing.

The model can help you better understand the scale and magnitude of different stressors on communities of animals living on the seafloor — and better understand the effectiveness of interventions. This understanding can support pragmatic decision-making to help the seafloor recover.

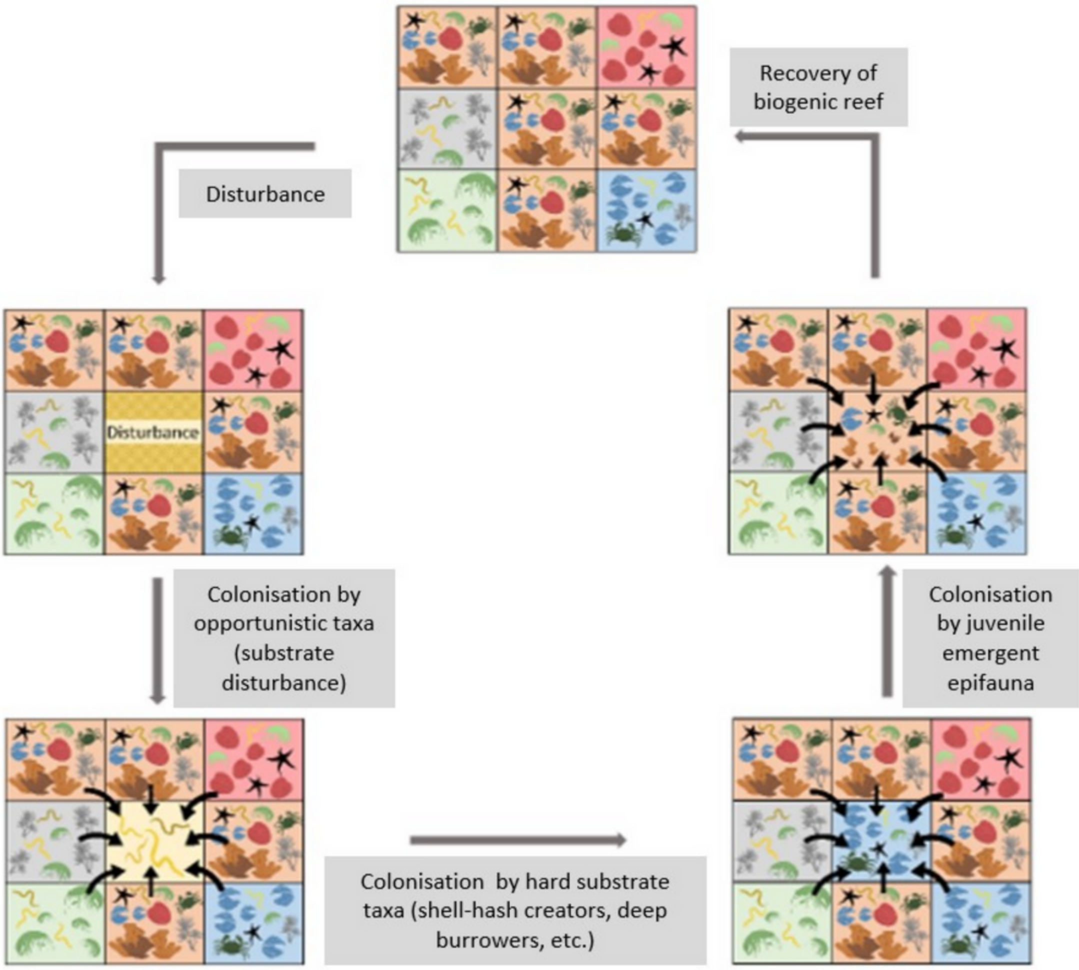
You can use the model to explore the effects of different scenarios when it's too difficult or expensive to empirically test these scenarios at scale. You can set different scenarios by entering different types of data.

A model can't accurately predict real distributions of species, but it can give you an overall understanding of ocean ecosystem recovery under different intervention scenarios. The Seafloor Disturbance Model can help you understand, 'how big of a change do we need to make to actually get the recovery?'

A decision support tool based on mathematical modelling of scenarios

This model is a spatially explicit decision support tool, coded in MATLAB programming software. The model explores how two stressors — sediment from land and seabed disturbance through bottom-contact fishing — impact the abundance and distribution of seafloor communities.

The model visualises the seafloor as a grid of cells, that each represents a habitat patch and the animals that live in it (see figure 2). At each timestep in the model, natural processes and disturbances occur within each cell, like growth, aging, mortality, predation, competition and recruitment, and fishing and sedimentation.



Functional group name	Opportunistic limited substrate disturbance	Opportunistic substrate disturbance	Tube-mat forming	Surface bioturbators	Shell hash creators	Epifaunal biogenic structure	Deep burrowers	Predators and scavengers
Visually dominating species in each functional group								
Representation of a grid cell with visually dominating species								

Figure 2: depiction of the disturbance and recovery cycle and the eight functional groups of the Seafloor Disturbance Model. Each functional group is colour coded to show the transition from a disturbed community (yellow cells) through colonisation, growth, and aging to a mature community (orange cells).

Using the model allows you to simulate different scenarios that change the extent and frequency of each stressor to see the impact on the seafloor community. For example, you could create scenarios like reducing fishing intensity or introducing marine protected areas (see figure 3).

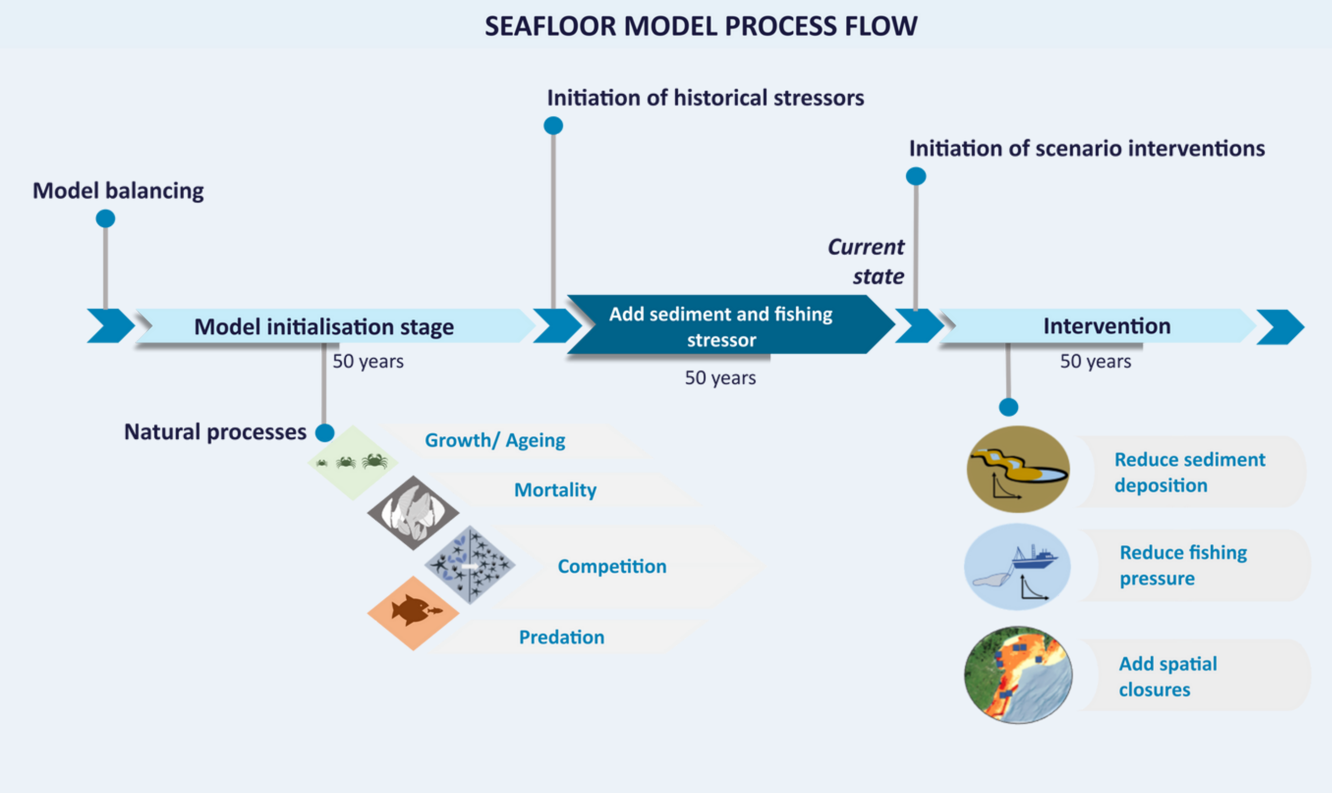


Figure 3: flowchart showing the model process flow during a simulated scenario

Eight groups of seafloor invertebrates

The model includes eight groups of seafloor invertebrates that are commonly found in soft sediment seafloor ecosystems, for example deep burrowers and predators and scavengers (see figure 2). Each group has different life history characteristics such as lifespan, age of maturity, and dispersal characteristics. This information is based on empirically derived life history data.

The model also includes relationships between settlement habitat (for example, shell hash) and colonisation by some groups (for example, epifaunal biogenic structure-formers).

You can use the model to explore impacts on all eight groups. You can also focus in on habitats of particular interest, such as the sponge gardens, sea pen meadows, and bryozoan reefs that comprise the epifaunal biogenic structure-forming group.

The response to stressors of each of the eight groups is based on empirically derived data representing the likelihood of mortality from a disturbance event. When groups 'die' within cells, that group is no longer present in that cell, nor are the ecological functions that the group provides for example, shell hash as a settlement substrate or habitat structure.

At each time step, colonisation by each group can occur if adults of that group are present in neighbouring cells (see figure 2).

Stressor scenarios can describe the current state and evaluate potential impacts

The model uses stressor scenarios to help describe the current state of seafloor communities, based on historical stressor information (see figure 4). Spatial data representing bottom trawling and sediment mud content can be used to see how existing stressors have likely impacted on seafloor communities, using stressor response curves from empirical studies (see figure 4).

You can also use the model to explore scenarios to evaluate the potential impacts on seafloor communities of changes in fishing and sediment stressors. For example, you can find out the magnitude of recovery that's likely for particular management interventions.

Exploratory scenarios for fishing stressors could include reducing fishing intensity (the number of trawl events) or closing spaces (areas where bottom trawling is restricted).

Exploratory scenarios for sediment stressors could approximate reductions in land-based sediment inputs that result in sediment deposits on the seafloor. These scenarios are modelled through assuming a direct relationship between seafloor mud content and land-based sediment inputs.

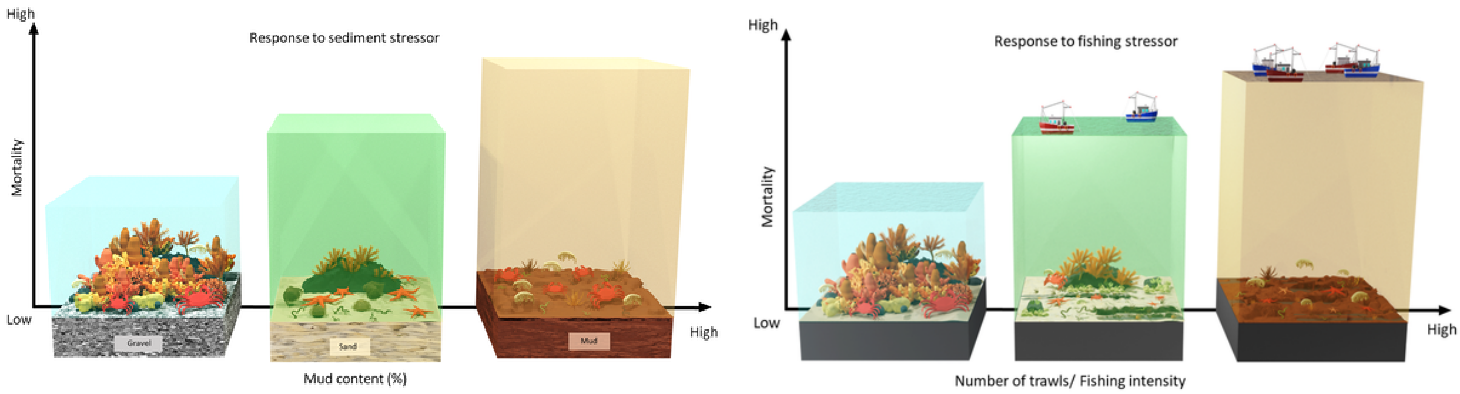


Figure 4: graph showing the relationship between fishing intensity and sedimentation and the probability of seafloor survival in the grid cell

Extra information about model assumptions and data requirements

The Seafloor model is designed to represent a typical seafloor invertebrate community in Aotearoa New Zealand. The eight functional groups exist worldwide, though the relative abundance of each group (for example, bivalves) may differ with geography and depth.

- The model assumes a constant rate of change in sediment, though the code could be modified to implement time lags in the response of sediment inputs to management interventions.
- The model assumes sediment is transported and deposited equally throughout the model area. If available, hydrodynamic models could be used to add further complexity of sediment inputs (for example varying inputs between different rivers) and where sediment is deposited, based on knowledge of currents, winds, and tides.
- The model assumes any increase or decrease in sediment supply is directly proportional to percent change in mud content on the seafloor. However, historical sediments may stay in place on the seafloor even when sediment supply is reduced, so the model may overestimate rates of recovery.
- Fishing data is rarely available at fine temporal and spatial resolution, and the trawl impacts must be calibrated to the model scale.
- Spatial maps of seafloor sediments and seafloor communities are rarely available, or if available, are often based on coarse resolution models that have not been verified.
- To apply the model in a new location, you need to select the model boundaries (for example, the Hauraki Gulf Marine Park), the model layers that represent the current sediment state, the fishing footprint, and any anticipated changes in sediment inputs (see table 1).

Table 1: Data requirements to run the Seafloor Disturbance Model

Element	Data	Resource
Sediment stressor	Seafloor sediments	Sediment grain size (% mud content)
	Sediment inputs (for example, riverine inputs, or dredge soil)	SedNet Tool, dredge disposal footprint
	Sensitivity of seafloor communities to mud content and grain size	Stressor response curves based on empirical data, already coded in model, but could be varied to fit site-specific information
Fishing stressor	Fishing intensity	Number of trawls per timestep, number of active vessels, and trawl length and width
	Fishing footprint	Spatial closures (for example, marine reserves) and seasonal closures
	Sensitivity of seafloor communities to bottom trawling	Stressor response curves based on empirical data, already coded in model, but could be varied to explore changes in gear type and impact
Life history stages	Age of reproductive maturity, post settlement or adult dispersal from source cell, reproductive seasonality, maximum lifespan	Based on published studies on representative information for each group

For more information

This model has been used to inform ecosystem-based management for multiple Sustainable Seas projects, including Phase 1: Project 5.1.2, Spatially explicit decision support tools; Phase 1 Project Enabling EBM, Tasman and Golden Bays case study; Phase 2: Project S1: EBM in Action: Hawke's Bay regional study; and Phase 2 Project 1.1: Ecological responses to cumulative effects.

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