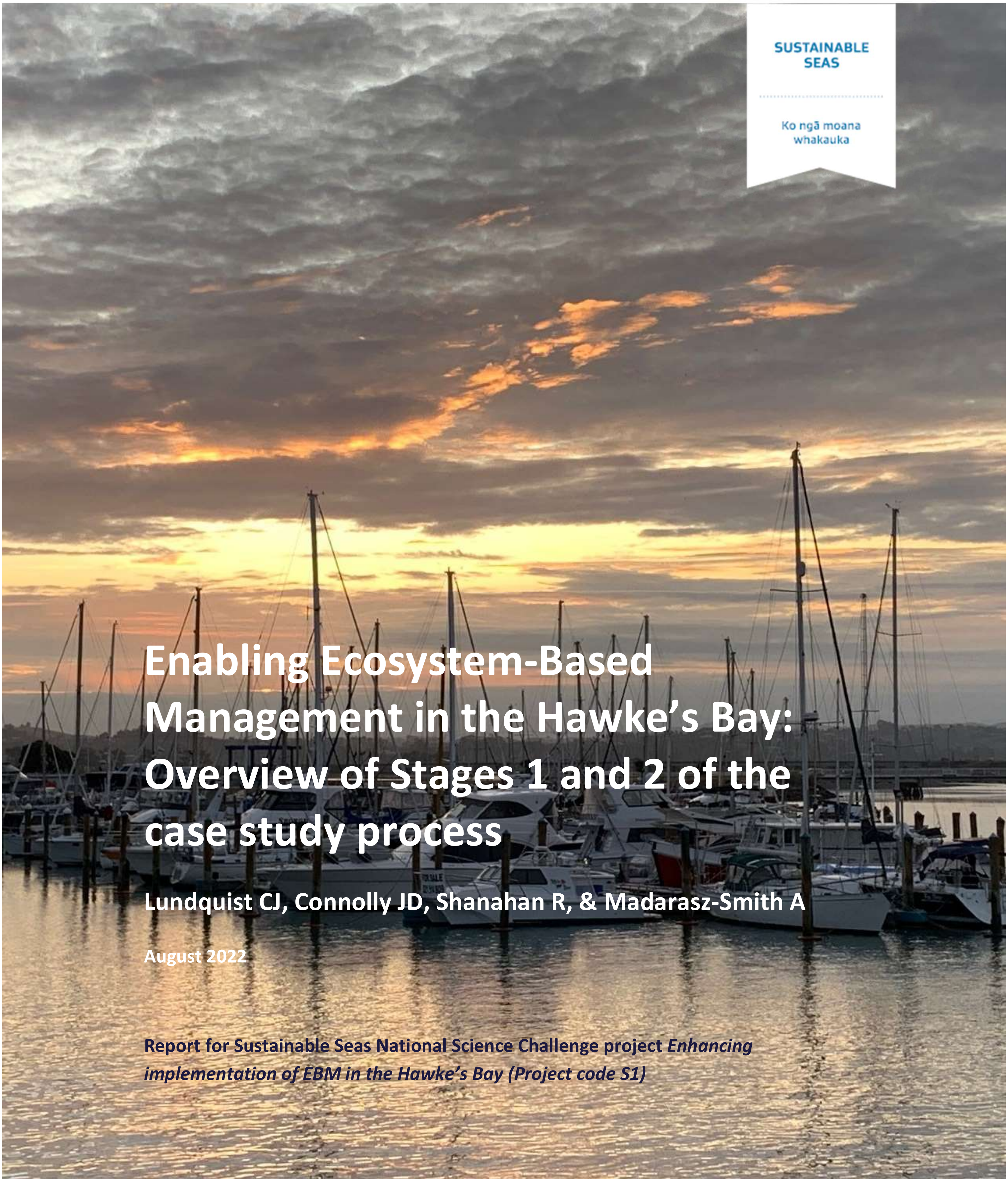

Enabling Ecosystem-Based Management in the Hawke's Bay: Overview of Stages 1 and 2 of the case study process

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August 2022

Report for Sustainable Seas National Science Challenge project *Enhancing implementation of EBM in the Hawke's Bay (Project code S1)*

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For more information on this project, visit: https://www.sustainableseaschallenge.co.nz/our-research/hawkes-bay-regional-study/

About the Sustainable Seas National Science Challenge

Our vision is for Aotearoa New Zealand to have healthy marine ecosystems that provide value for all New Zealanders. We have 60+ research projects that bring together around 250 scientists, social scientists, economists, and experts in mātauranga Māori and policy from across Aotearoa New Zealand. We are one of 11 National Science Challenges, funded by the Ministry of Business, Innovation & Employment.

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Cover image: Ahuriri marina, Hawke's Bay (C. Lundquist).

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Executive summary

The Hawke's Bay case study was selected as one of the Sustainable Seas National Science Challenge's Phase 2 case study areas for research on implementing ecosystem-based management in a real-world context, using tools, processes and analyses developed within Challenge research. This project used system mapping and spatially explicit decision support tools to explore the effects of multiple stressors on seafloor communities, including how these communities respond to stressors at different spatial and temporal scales, and potential time lags in response and recovery from stressor impacts. The project is a collaboration with the Hawke's Bay Marine and Coastal Group, a non-statutory multi-agency, multi-stakeholder group established in 2016 in recognition of concerns over the apparent reduction of inshore finfish stocks and environmental degradation in coastal and marine areas of Hawke Bay.

Stage 1 (2019-2020) of this project developed a qualitative system map based around two main stressors of the marine environment – increasing sedimentation and the loss of benthic structure. The System map was also used to identify available knowledge, and gaps in knowledge, for different elements of the system map. In Stage 2 (2020-2022) of the project, an existing model of seafloor invertebrates was selected for application to the Hawke's Bay. In applying the Seafloor model to the Hawke's Bay, scenarios were used to explore how different interventions (e.g., changes in fishing intensity or the spatial distribution of fishing, reductions in land-based sediment impacts) might increase ecosystem health of the Hawke's Bay. Hawke's Bay specific datasets on seafloor sediments, sediment inputs from land from each of the major rivers, and the bottom trawl fishing footprint were used to populate the tool for the Hawke's Bay case study. In a final workshop, the two tools (the Seafloor model and the System map) were coupled to explore how these tools might work together using an Analogue Simulation approach.

The Hawke's Bay application illustrates a further application of two tools used previously in the Challenge, system mapping and the Seafloor model, in a place-specific context to explore EBM.

Introduction

Sustainable Seas National Science Challenge

The Sustainable Seas National Science Challenge, initiated in 2014, is one of 11 Ministry of Business, Innovation and Employment-funded Challenges aimed at taking a more strategic approach to science investment. The Challenge Objective is: "*to enhance utilisation of our marine resources within environmental and biological constraints*" and its Mission is: "*to transform Aotearoa New Zealand's ability to enhance our marine economy, and to improve decision-making and the health of our seas through ecosystem-based management* (EBM)". EBM is a holistic and inclusive approach to managing marine environments, their competing uses, and the ways New Zealanders value them (Hewitt et al. 2018). While Sustainable Seas does not have the mandate to 'implement' EBM, it will provide underpinning research and tools to support the design and implementation of an EBM approach tailored to Aotearoa New Zealand. Partnering with central and regional government, industry, other stakeholders, and Māori is critical for the implementation of EBM and the success of the Challenge.

Phase 2 (2019-2024) of the Challenge selected multiple case studies to inform and enable EBM approaches to decision-making through partnerships with interested regional or central government agencies. These case studies are designed to serve as proof of concept of EBM approaches and provide key lessons about putting theory into practice to further enable EBM in Aotearoa New Zealand.

The Hawke's Bay case study was selected as one of the Challenge's Phase 2 case study areas for research on implementing ecosystem-based management in a real-world context, using tools, processes and analyses developed within Challenge research. Hawke's Bay is representative of a typical coastal marine ecosystem with sandy beaches, inter-tidal reefs, dunes, estuaries and subtidal reefs and soft sediments. The region has large river systems, fisheries, productive lands and ocean outfalls which can add stress to the marine system and impact on people's values for the coastal area. An initial meeting with the Hawke's Bay Marine and Coastal Group (HBMaC) identified the potential impacts of two overlapping stressors (sediment delivery to the Hawke's Bay from land, and the effect of seabed disturbance through bottom contact activities) and their importance for the health and recovery of the Hawke's Bay marine ecosystem, as the focus of this case study project.

The Challenge objective is directly aligned with the HBMaC vision: "*to achieve a healthy and functioning marine ecosystem that supports an abundant and sustainable fishery*". This project sought to explore the potential scope of change necessary to achieve the desired outcome of achieving an abundant fishery in the Hawke Bay. The project's purpose was not to determine or recommend specific policy or intervention options.

Hawke's Bay Marine and Coastal Group (HBMaC)

HBMaC is a non-statutory multi-agency, multi-stakeholder group established in 2016 in recognition of concerns over the apparent reduction of inshore finfish stocks and environmental degradation in coastal and marine areas of Hawke Bay. HBMaC is comprised of representatives from local and central government councils and agencies, tangata whenua, the forestry industry, and recreational and commercial fisheries (Figure 1). HBMaC members recognise the complexity of the Hawke's Bay terrestrial, coastal and marine environments and the need for collaboration between organisations with a mandate for its management and those who use and value the area. HBMaC developed a roadmap to address the information gaps highlighted in the 2016 marine review in order to "*ensure the restoration and ongoing health of the Hawke's Bay marine environment including an abundant fishery for future generations"* (HBMaC Research Roadmap).

Figure 1: HBMaC vision and agencies represented during Sustainable Seas case study project. Adapted from HBMaC Research Roadmap.

HBMaC produced a roadmap for research into three themes: terrestrial and coastal linkages, ecosystems and habitats, and fisheries (Figure 2). Research undertaken by the group is underpinned by eight principles, each supported by "*values that define HBMaC participants' connection to and aspirations for the coastal marine area*" (HBMaC Research Roadmap). The group utilises an interdisciplinary approach and acknowledges the diversity of cultures, perspectives, and expectations around the coastal and marine area (HBMaC Research - Roadmap). HBMaC has been held up as an example of the application of EBM principles in Aotearoa New Zealand (Hewitt et al. 2018).

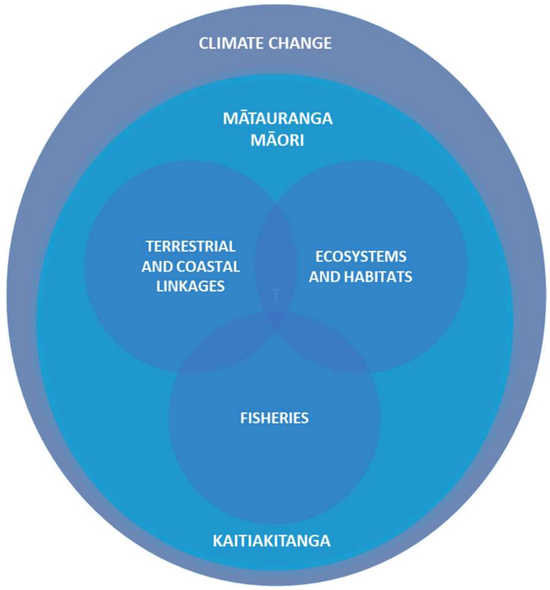

Figure 2: Three research themes of HBMaC and their location within a mātauranga Māori – kaitiakitanga framework/understanding that acknowledges the potential effects of climate change. Adapted from HBMaC Research Roadmap.

An overview of the case study process

An initiation workshop was undertaken in November 2018 where Sustainable Seas researchers and HBMaC group members met to discuss the scope of the potential project. Two consistent themes were identified as having the greatest perceived influence on the Hawke's Bay coastal marine area (CMA): sedimentation from land and disturbance of the seafloor by fishing activity.

Cumulative impacts from multiple stressors were discussed, and better understanding of the spatial footprint of these stressors was considered to be a key knowledge gap.

Following further scoping of the project with Sustainable Seas and project team, the project was separated into two stages:

Stage 1 (2019-2020) developed a qualitative system map based around two main stressors of the marine environment – increasing sedimentation and the loss of benthic structure (hereafter the System map). This was completed in early 2020. This project is described in:

- Connolly JD, Lundquist CJ, Madarasz-Smith A & Shanahan R (2020). Hawke's Bay EBM case study - Part 1: System mapping to understand increased sedimentation and loss of benthic structure in the Hawke's Bay. A report for the Sustainable Seas National Science Challenge. Hamilton, New Zealand: Deliberate. 94 p.

Stage 2 (2020-2022) was scoped after the completion of Stage 1. To explore potential improvements in seafloor health of any actions to mitigate against the two previously identified stressors (sedimentation from land and seafloor disturbance from fishing activity), an existing model of seafloor invertebrates (hereafter the Seafloor model) was selected for application to the Hawke's Bay. Through a series of workshops, HBMaC engaged with the Seafloor model, and developed scenarios representing potential management interventions. In a final workshop, the two tools (the Seafloor model and the System map) were coupled to explore how these tools might work together using an Analogue Simulation approach. Stage 2 is described in three aligned reports, outlined below:

- This report provides an **overview of the process** for the entire case study.
- A detailed description of the **Seafloor model** is provided in: Lundquist CJ, Bulmer RH, Yogesh N, Allison A, Leunissen E, Brough T. (2022). Development of a seafloor model of disturbance impacts on benthic structure in the Hawke's Bay. Report prepared for the Sustainable Seas National Science Challenge. Hamilton, New Zealand: NIWA. 32 p.
- A detailed description of the **Analogue Simulation** is provided in: Connolly JD, Lundquist CJ, Shanahan R & Madarasz-Smith A. (2022). Hawke's Bay EBM case study - Part 2: Applying Analogue Simulation - A qualitative process to explore the socio-ecological flow-on impacts in a system in response to modelled biophysical changes. Report prepared for the Sustainable Seas National Science Challenge. Hamilton, New Zealand: Deliberate. 33 p.

The two stages within the case study and how they fit together sequentially are conceptualised in Figure 3.

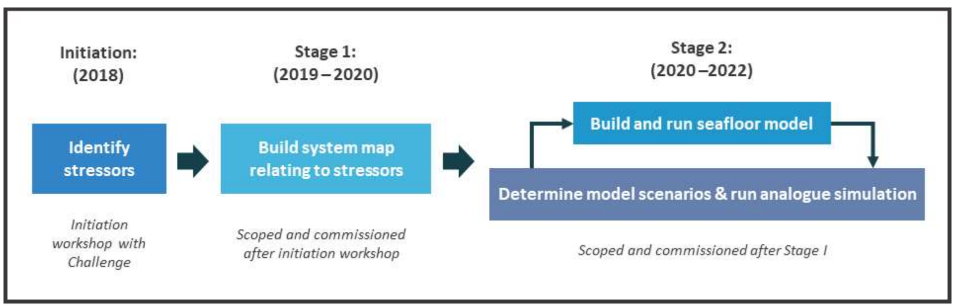

Figure 3: Conceptual map of Stages 1 and 2 in this case study

Stage 1 – Development of the System map

System mapping is a visual tool that builds a picture of interconnected factors contributing to, and impacted by, a certain issue(s) of interest. It specifically focuses on the circular nature of these relationships and how they 'feedback' on themselves and each other. A system map is used in two main ways:

- To visualise inter-connectivity: A system map highlights the interconnected nature of factors within the system. In particular, the map shows where there is circular influence, demonstrating how much influence comes from 'within' the system, versus 'outside' of it.

- To explore changes over time: The map supports discussion of what the likely change in the system will be over time, based on proposed actions to be taken. Example outcomes of these types of discussion are shown as a graph.

A system map can help identify areas where interventions may have the maximum impact in terms of reducing the stressors identified. While this approach does not go as far as identifying management interventions, it can identify areas where management interventions may occur.

A System map for the Hawke's Bay marine region was created in Stage 1 (Figure 4, Connolly et al. 2020). The system mapping exercise involved HBMaC participants in a half day introductory workshop and three full-day system mapping workshops, all of which were held in person, interspersed with kanohi ki te kanohi (face to face) conversations to provide individual perspectives to inform the system map. The three full-day workshops were held in February and March 2020.

Within the system map, you can see how everything is connected: land-based influences of sediment runoff are on the left; physical influences on the amount of benthic structure are in the middle; and the social impacts on and from the seafood stocks in the Hawke's Bay are on the right (Figure 4).

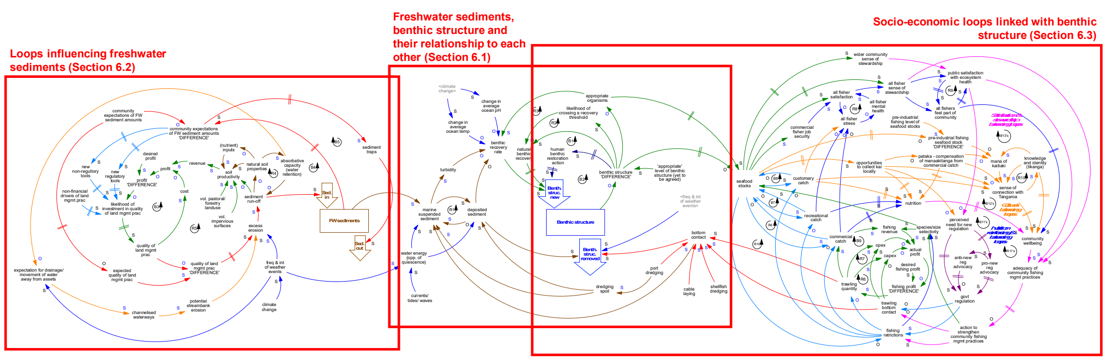

Figure 4: System map of the Hawke's Bay coastal region developed in Stage 1. A higher resolution map and the associated report (Connolly et al. 2020) are available at: https://www.sustainableseaschallenge.co.nz/our-research/hawkes-bay-regional-study/.

The System map was also used to identify available knowledge, and gaps in knowledge, for different elements of the system map. Knowledge sources include scientific data as well as traditional and anecdotal sources of knowledge. A list of metadata for existing environmental and socio-cultural datasets that could be used populate scenarios, or more broadly inform discussions, was collated and included in the System map report (Connolly et al. 2020).

Further information on the System map can be found in Connolly et al. (2020).

Stage 2 – Seafloor model and Analogue Simulation

In Stage 2, a Seafloor model developed earlier in the Sustainable Seas Challenge was selected to explore potential changes in seafloor benthic structure following changes in the two stressors of interest (sedimentation from the land and bottom trawling intensity). The Seafloor model was then coupled with the System map from Stage 1. The results of the Seafloor model were used as inputs to a qualitative Analogue Simulation process to explore the flow on impacts of the changes modelled in the Seafloor model in the system map.

Stage 2 included a series of steps:

1. The Seafloor model was adapted to the Hawke's Bay marine region. Relevant data on sedimentation from land and fisheries, for which metadata were collated in Stage 1. These layers were acquired and used to build and parameterise the Hawke's Bay Seafloor model.

2. The aims of Stage 2 and the Seafloor model were presented to the group at virtual meetings. Exploratory scenarios that showed impacts of changing individual stressors on benthic structure were modelled and presented to HBMaC participants.

3. Final scenarios were developed by HBMaC participants during a virtual workshop. These scenarios focused on changes (or not) in three main factors relating to the two stressors of sedimentation and fishing effort.

    - Reducing fishing effort (spatially and/or in intensity);
    - Adding spatial areas that were closed to fishing, in addition to existing closures; and
    - Reducing sediment load from rivers (an average of all rivers in the Bay)[1].

4. These three scenarios were then modelled to assess implications for benthic structure. A fourth 'baseline' scenario represented no reductions in stressors from the current state. A projection of the estimated mature benthic structure over the next 50 years, in response to these changes, was one of the key model outputs.

5. The final outputs from these four scenarios were then used as input information to a discussion that explored their flow on impacts in the socio-ecological and cultural space, i.e., what are the implications for societal objectives such as community wellbeing, or fisher job security, or cultural identity. This Analogue Simulation exercise used the System map as a guide and applied a novel method of qualitatively exploring the relative impacts of such changes over time.[2] This exercise occurred during a full-day virtual workshop in March 2022.

Regional council marine science, land science and policy staff were also part of the project, serving as technical specialists regarding the appropriateness of input data and to help inform approximately what macro-quantities of sediment reduction are being talked about elsewhere (in the HBRC area) and what the estimated pre-European/human levels of sediment were.

[1] The reduction of sediment into the Bay was then evenly spread across the Hawke's Bay model domain.
[2] Project resourcing allowed three final scenarios to be modelled in addition to a 'no change' baseline scenario. These scenarios attempted to represent a range of changes to sediment inputs and bottom contact from fishing pressure available in the model, to help give the HBMaC group an idea of the potential magnitude of different management interventions.

Overview of the Seafloor model

A Seafloor model of disturbance and recovery dynamics of seafloor invertebrates was selected for application in Stage 2 of the Hawke's Bay case study, as this tool allowed for exploration of one of the key elements of the System map, benthic structure. Benthic structure refers to the animals living on the seafloor that form three dimensional structures. The Seafloor model is an adaptation of a spatially explicit decision support tool that was previously applied in Phase 1 of the Sustainable Seas Challenge to explore impacts of multiple stressors (sediment deposition, seafloor fishing impacts) in Tasman Bay and Golden Bay. The Hawke's Bay application illustrates a further application of this tool in a place-specific context to explore EBM.

Models are often used to explore potential changes in marine ecosystems under possible future scenarios, when it is not feasible to empirically test these scenarios at the temporal and spatial scale that is required to understand system dynamics. For coastal marine ecosystems, we need to understand the effects of multiple stressors on seafloor communities, including how these communities respond to stressors at different spatial and temporal scales, and potential time lags in response and recovery from stressor impacts. When stressors such as sediment and fishing impacts occur at large scales over areas of high environmental variability, it is difficult to assess impacts due to species-specific responses to multiple environmental drivers (e.g., wave exposure, sedimentation, turbidity, depth). Decision support tools can be used to predict changes in seafloor community dynamics at scales relevant to science and management perspectives that are difficult or expensive to examine empirically.

The disturbance model is a spatially explicit decision support tool (coded in Matlab programming software) that explores how the spatial extent and frequency of disturbances (by sediment or fishing) impact on the abundance and distribution of animals living on the seafloor. The model can be visualised as a series of cells, each representing a habitat patch and the animals that live within it. The model includes eight categories of seafloor invertebrates, and the focal group in the case study was the benthic structure group, consisting of habitat-structure forming epifaunal invertebrates (animals that live at and above the surface of the seafloor such as those that form sponge gardens, sea pen meadows, and bryozoan reefs). At each timestep in the model, natural processes (growth/aging, mortality, predation and competition) and other disturbances (e.g., fishing) occur within each cell. Reproduction is determined by the 'age' of animals in each cell, and the dispersal of larvae or recruits into adjacent cells is determined by estimated distances of planktonic larval dispersal that are specific to each group, and based on field or experimental data. Natural mortality or other disturbances (based on rates that are defined for each scenario) occur at each timestep, and result in impacts on the groups in each cell. The response to stressors of each of the eight invertebrate groups is based on empirically-derived data representing the likelihood of mortality from a disturbance event. Once a disturbance occurs, a group may 'die', and the cell can be repopulated in later timesteps if colonists are available from neighbouring cells (Figure 5).

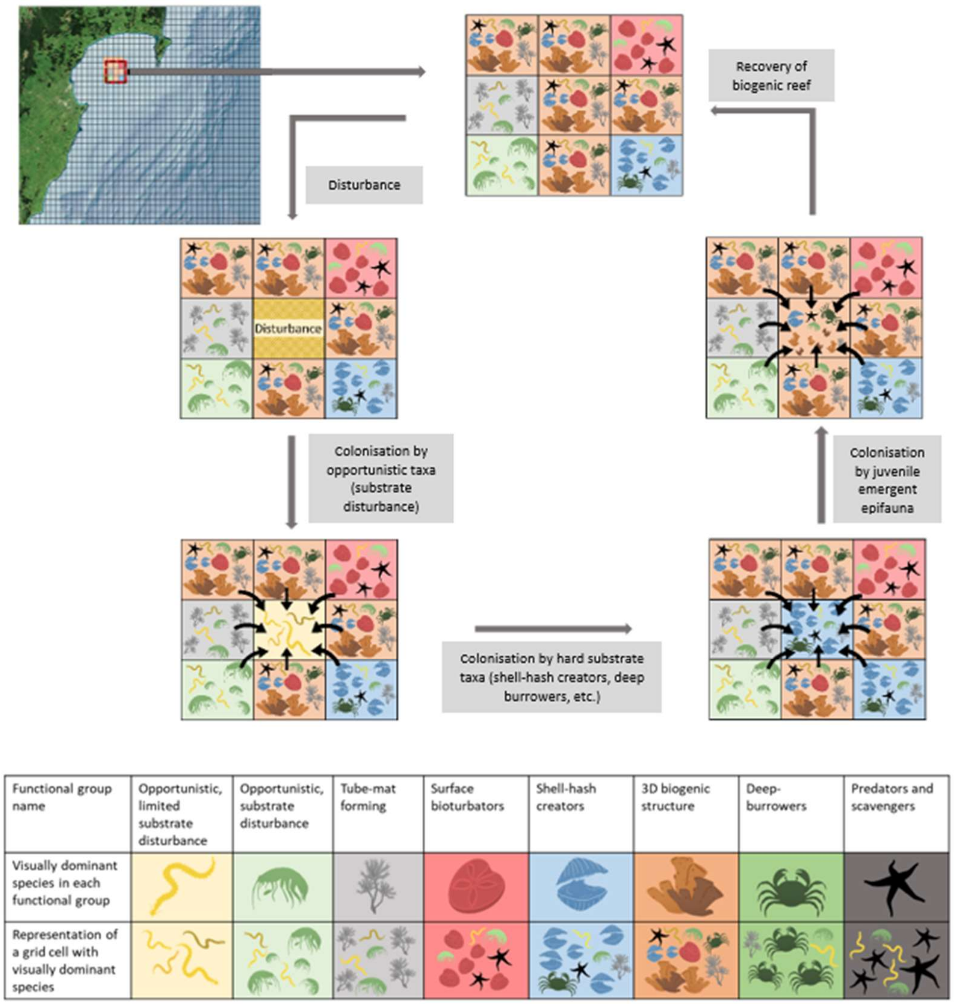

Figure 5: Conceptual diagram of the different types of animals in the seafloor model, and a typical time cycle showing disturbance and recovery. Communities represent benthic species assemblages dominated by different types of animals, and are colour coded to show transition from a disturbed community (pale cells) through colonisation and growth/aging to a mature community (orange cells) dominated by benthic-structured organisms.

In applying the model to the Hawke's Bay, scenarios were used to explore how different interventions (e.g., changes in fishing intensity or the spatial distribution of fishing, reductions in land-based sediment impacts) might increase ecosystem health of the Hawke's Bay. Hawke's Bay specific datasets on seafloor sediments, sediment inputs from land from each of the major rivers, and the bottom trawl fishing footprint were used to populate the tool for the Hawke's Bay case study. The case study region was selected to include the Hawke's Bay Coastal Marine Area, as well as the central portion of Hawke Bay that is offshore of the regional council boundary (Territorial Sea) to represent a more ecologically continuous area. This area includes a deepwater (>200 m) region that was retained, though no management actions were proposed for this deepwater area.

Within a model simulation, a start-up or initialisation stage occurred, followed by implementation of a 50-year period of historical stressors (Figure 6). Historical sediment stressors were based on the map of current sediment mud content, and fishing stressors were based on the average bottom trawl fishing footprint based on available data from Fisheries New Zealand. Following this 50-year period, the model was assumed to provide an estimate of the 'current' state of benthic structure on the seafloor. Each scenario then started from this 'current' state, but during the intervention period, different stressor options were applied, and the change in benthic structure followed for 50 years (Figure 6). The model is stochastic[3], and random variations such as high mortality or high recruitment events that do occur naturally, could occur.

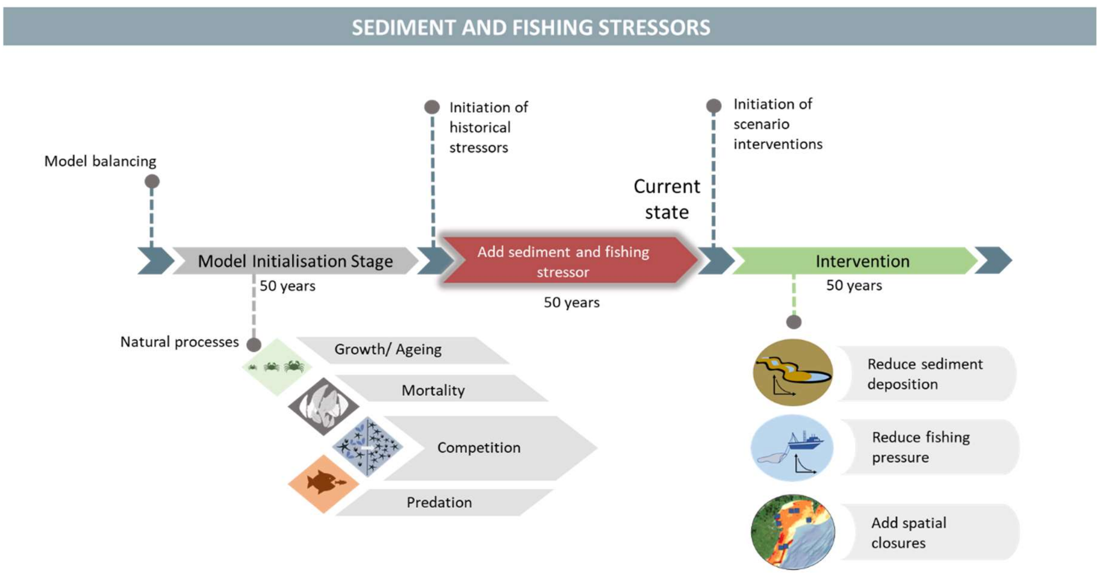

Figure 6: Flowchart illustrating model flow and processes applied during a model scenario.

Sediment datasets included spatial maps obtained from the Hawke's Bay marine information review (Haggitt and Wade 2016) and represent types of soft sediment habitats (e.g., mud, sand). These abiotic habitat layers were updated with new information from Hawke's Bay Regional Council sediment surveys and side-scan data of the Wairoa Hard and the Clive Hard. Sediment layers were converted into values representing the percent mud content at the seafloor. Sediment riverine inputs were estimated using the SedNet[4] tool, which provides annual loading from each of the major rivers (Figure 7), allowing HBMaC to see relative contributions within the Hawke's Bay region to seafloor sediment inputs.

Fisheries data were provided by Fisheries New Zealand, and represented an annual average fishing footprint (converted from number of trawls per km^2 to match model grid cell resolution). Existing spatial closures (e.g., Clive Hard, Mahia Peninsula, Te Angiangi Marine Reserve, and Wairoa Hard) were represented as closed areas within the fishing footprint. Mortality of each group, when subjected to either sediment or fishing disturbance, was based on empirical data relating either the number of fishing events (trawls on the seafloor in a grid cell within a time step), or the sediment mud content, to likelihood of mortality occurring within that time step (illustrated in Figure 8).

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[3] Involving processes that are described by random probability distributions
[4] http://tools.envirolink.govt.nz/dsss/sednet/

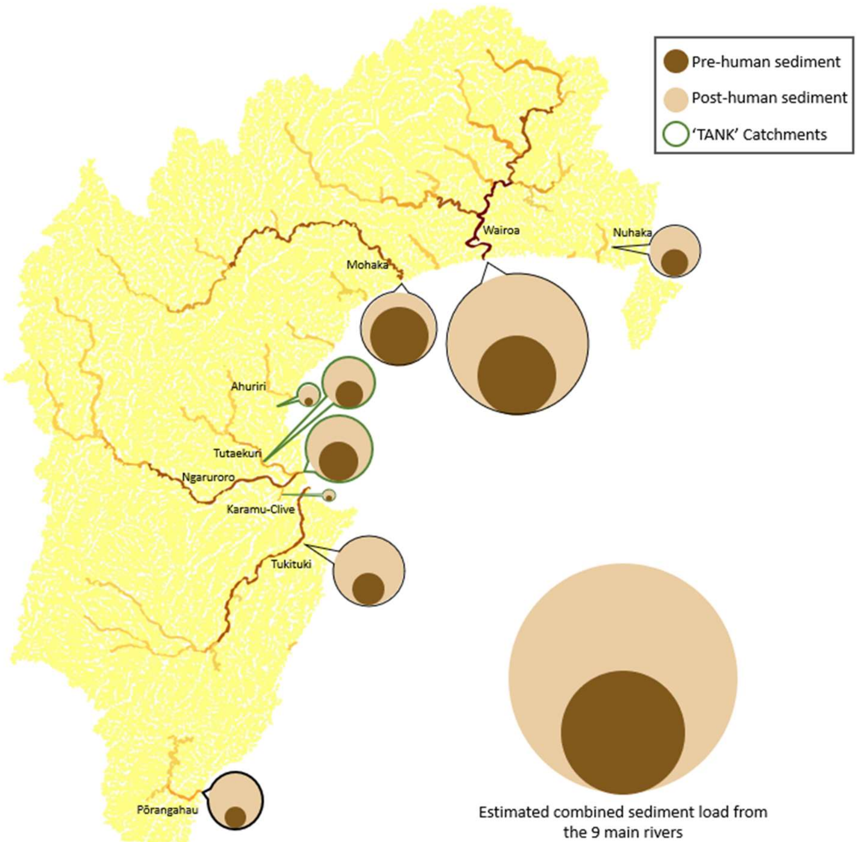

Figure 7: Estimated sediment inputs from major catchments in the Hawke's Bay region.

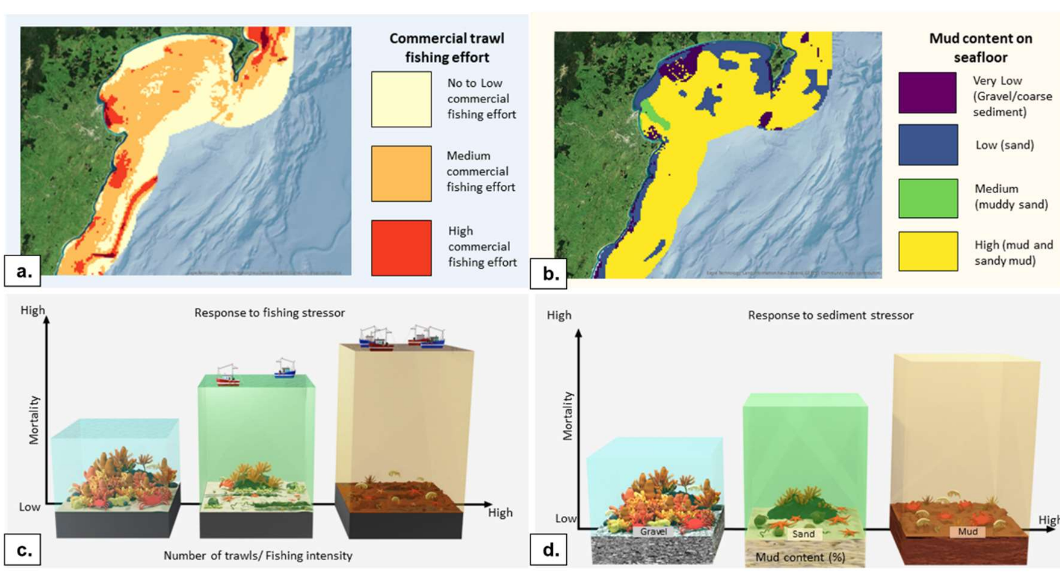

Figure 8: Fishing (a) and sediment (b) stressor maps applied in the Seafloor model. Example aquaria showcase changes in benthic structure with increasing fishing (c) and sediment (d).

Overview of Scenario development and the Analogue simulation exercise

The Analogue simulation exercise has three important parts:

1. Determine the starting conditions;
2. Set up the Analogue simulation space; then
3. Run the Analogue simulation exercise.

Determining the starting conditions is effectively like parameterisation of a model. The key questions that need to be answered before running the Analogue simulation exercise are:

- What is the overall timeframe of the simulation?
- What will the timesteps be within that timeframe?
- What part (all or some) of the System map will be used to guide the Analogue simulation?
- What are the key factors for which changes will be estimated and tracked?
- What are the key delays between these factors?
- What are the 'starting condition' levels for each of those factors?
- Determine a relative scale of change for factors for each timestep (consistent across all).

Setting up the Analogue simulation space relates to how the exercise is run in conjunction with the System map. The exercise appears similar to a 'board' in a board game (although this process is not designed as a game).

An example of how the simulation space was set up for this exercise is shown in Figure 9.

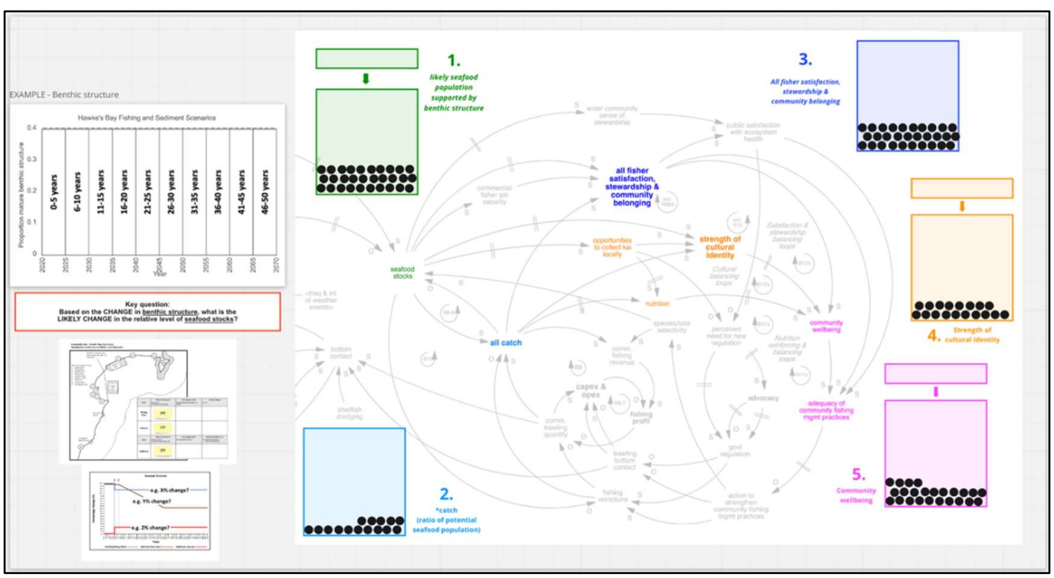

Figure 9: Example of a prepared Analogue simulation space.

Importantly, is it critical for the success of the Analogue simulation process that the output graphs from the Seafloor model are only revealed timestep by timestep, as the exercise is undertaken. Participants only see the results of the modelling for the timestep they are about to discuss immediately before discussing that timestep. Running the Analogue simulation exercise is then a matter of repeating a gradual reveal-discuss-update process with the group. These steps are outlined in Table 1, and described in detail in Connolly et al. (2022).

Table 1: Process for each timestep in each scenario.

Step	Step description	
Reveal the change in the current timestep on the input graph* * (one timestep at a time only)	The change in the current timestep on the input graph is revealed. As noted earlier, in this case study the benthic structure graph that is the output of the seafloor model is the input graph for this exercise.	
	One at a time, discuss how each factor may change in response to changes in those factors that influence it – directly or indirectly. Amounts of each factor are represented by tokens. This is informed by knowledge if available, otherwise discussion within the group. This was done in the following order with the following supporting knowledge.	
	Factor (in order):	**Change in factor informed by:**
Discuss and update the flow on impacts from that factor to and through the other factors in the system diagram.	Seafood stocks	Look-up table estimating benthic structure impact on fish stocks. Refer to Connolly et al. (2022) for details.
	All catch	Assumed as half of seafood stocks. This does not infer the catch is half of the stock. It simply allows enough tokens to represent changes in the catch.
	All fisher satisfaction	Change determined by the group in discussion.
	Strength of cultural identity	Change determined by the group in discussion.
	Community wellbeing	Change determined by the group in discussion.
Repeat steps 1 and 2 for all 10 timesteps of each scenario, then the scenario is completed.		

The scenarios modelled

Four scenarios (three intervention scenarios and one baseline scenario) were modelled using the Seafloor model to reflect potential interventions relating to reductions in sediment inputs into the Hawke's Bay, and reductions in fishing disturbance to the seafloor through either reduction in fishing intensity or addition of spatial closures (Table 2). For more detail, see Connolly et al. (2022) and Lundquist et al. (2022).

Table 2: Description of scenarios modelled.

Scenario	Brief description	Changes in model variables		
		Sedimentation	**Fishing effort**	**Spatial closures**
Baseline scenario	No change. The model variables remain at current levels. For the entire 50-year period of the simulation.	No change. Current sedimentation levels remain.	No change. Current levels of fishing effort and spatial variability remains.	No change. Current closures remain.
Scenario 1	Nearshore closure focus with some reduced fishing and sedimentation. A fishing closure similar to that surrounding Mahia Peninsula is extended to Porongahau. The closure width is approximately 2 NM (~3 km), in addition to existing closures. In addition, there is a reduction in fishing effort (5%) across the entire area, up to 200 m deep, and some sedimentation reduction of 10% over 25 years.	Sedimentation from all major rivers reduces by 10% over 25 years, i.e., 0.4% per year until reaching a level of 90% of current. Reduction start year: 2027 Reduction stop year: 2052	Fishing effort across all remaining areas outside of closures, within 200 m depth contour, reduced by 5%. Spatial variability within fishing effort remains.	Additional fishing closure within ~2 NM (3 km) of shore, in addition to existing fishing closures.
Scenario 2	Major inshore fishing reduction and moderate sedimentation reduction. No additional fishing closures. Existing closures remain. There is a major reduction in fishing effort of 30% within the Bay (inshore of a line between Mahia and Cape Kidnappers and a section off the mouth of the Porangahau River), and a 10% reduction in fishing effort everywhere else, up to 200 m depth contour. Moderate Sedimentation reduction of 15% over 30 years.	Sedimentation from all major rivers reduces by 15% over 30 years, i.e., 0.5% per year until reaching a level of 85% of current. Reduction start year: 2027 Reduction stop year: 2057	Fishing effort changed in two spatial areas. Area A: Inshore of a line between Mahia and Cape Kidnappers and a section off the mouth of the Porangahau River, reduced by 30%. Area B: Everywhere else within 200 m depth contour, reduced by 10%. Spatial variability within fishing effort remains.	No change. Current closures remain.
Scenario 3	Moderate inshore fishing reduction and major sedimentation reduction.	Sedimentation from all major rivers reduces by 25% over 40 years, i.e., 0.625% per year until	Fishing effort across all areas outside of closures, within	No change. Current

Scenario	Brief description	Changes in model variables		
		Sedimentation	Fishing effort	Spatial closures
	No additional fishing closures. Existing closures remain. There is a moderate reduction in fishing effort of 15% across the entire area, up to 200 m deep. Major sedimentation reduction of 25% over 40 years.	reaching a level of 75% of current. Reduction start year: 2027 Reduction stop year: 2067	200 m depth contour, reduced by 15%. Spatial variability within fishing effort remains.	closures remain.

Overview of results from the Seafloor model and the Analogue simulation process

An overview of the results from the Seafloor model and the Analogue simulation exercise are shown in Figure 11 below. For more details refer to Lundquist et al. (2022) and Connolly et al. (2022).

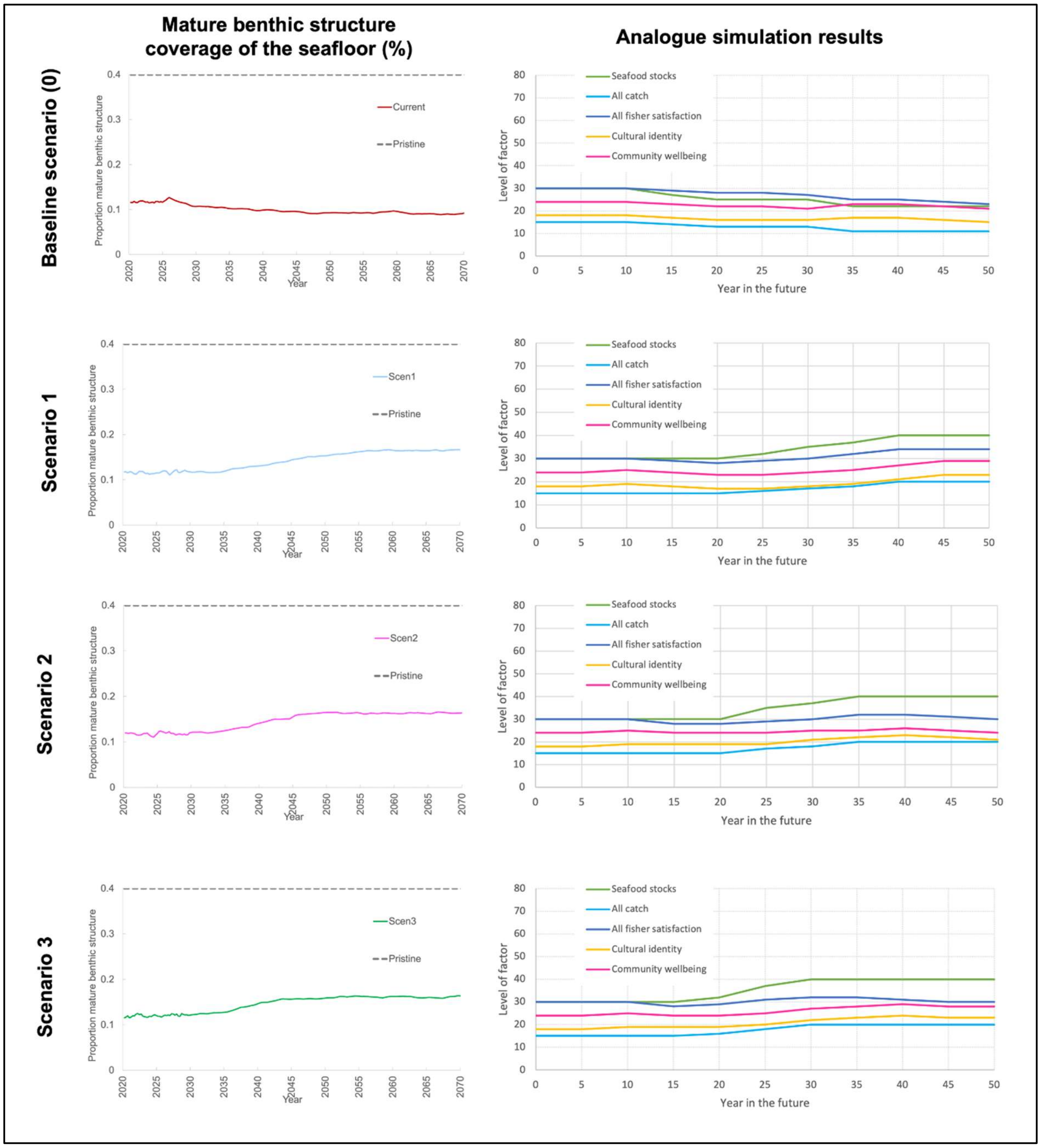

Figure 11: Example of a content provided for each scenario in the Analogue simulation space.

Useful insights and observations from the Analogue simulation participants were:

- It was likely ongoing action would be necessary, rather than a one-off change.
- There were often time lags between when actions were implemented, and the effect on benthic structure, or other elements of the System map.
- Participants were also surprised with the lesser than anticipated impact of what were perceived as large management interventions.
- Participants designed what they thought were three very different scenarios, however after 50 years, all scenarios all tended towards around a similar coverage of benthic structure. This result could be explained when comparing the total changes in each stressor across the three scenarios. Sediment scenarios differed in the speed of implementation of sediment reductions, however annual decreases in sediment were quite similar between scenarios, ranging from 0.4 to 0.625% per year. Fishing intensity was implemented at different rates across different areas of the model. After quantifying the relative contributions of each of the areas identified in scenarios to total fisheries catch, and how much of each area was either subject to a reduction in fishing intensity or a spatial closure, the combined reductions in fishing intensity were also similar across each scenario.
- Scenario outputs were provided as average change over the model area. However, changes in particular areas (i.e., those subject to spatial closures or to high reductions in fishing intensity) showed larger recovery of benthic structure.

Learnings from the case study

This section provides an overview of reflections from the authors about what lessons have been learned from the process. This section has also been informed by a short survey that the participants were invited to fill out online, after the process had been completed.

Table 3: Summary of learnings from the case study

<table>
<tr><th>Lessons learned</th><th>Reflections for future application</th></tr>
<tr><td colspan="2">Dealing with entrenched perspectives</td></tr>
<tr><td>Participants recognised that the process was about investigation of the drivers of system change and were broadly willing to put aside institution-specific beliefs about how the system operates in pursuit of improved scientific understanding.</td><td rowspan="2">Consider similar approaches like this in the future where involvement does not commit representative to a particular management recommendation or outcome.

The process is intended to increase the understanding participants have of the problem and potential ways to navigate forward, and this can still be achieved without participants committing to a particular management recommendation or outcome.</td></tr>
<tr><td>Because the members of the HBMaC group did not have any delegated decision-making powers, this meant their involvement was not seen as an endorsement of outcomes from the process.</td></tr>
<tr><td colspan="2">Increased understanding and insights</td></tr>
<tr><td>The System map was an useful tool for exploring the inter-relationships between factors.</td><td>The system mapping approach may be used on its own, or coupled with other approaches.</td></tr>
</table>

Lessons learned	Reflections for future application
The system mapping process revealed that there is a lot of discrepancy between how well certain parts of the system are understood by everyone.	Increased understanding of existing knowledge and knowledge gaps is one of the intents of the process, and helps achieve several things: • Makes existing levels of understanding explicit; • Seeks to expand the collective understanding of the group; • Highlights which other perspectives may be required.
The process of system mapping facilitated the development of a common system understanding.	Consider incorporating the system mapping process in whole or in part in other work.
Existing social capital was useful to enable a base platform to build upon in discussions.	Consider the existing social capital amongst a group when embarking on a participatory process.
The System map was a good tool for further building or enhancing social capital within the group.	Consider using a system mapping exercise in other processes to help build social capital.
The Seafloor model provided increased understanding of how seafloor ecosystems worked.	Consider using ecological models to inform understanding of marine ecosystems, in tandem with system mapping that explores how they are connected to societal, economic and cultural factors.
The Seafloor model and Analogue Simulation exercise together demonstrated the complexity of benthic structure and fishing to the participants, and highlighted that achieving the desired outcomes was unlikely to be a matter of simply choosing one intervention that would achieve this. Multiple interventions were likely required, resulting in most factors within the system being impacted by them.	Consider how to leverage the insights of the participants in this regard into further work on these matters.
It appeared that the process provided many members of the group with an output they were proud of and would be happy to share, although this may not apply to all participants.	Consider how participants can pass on their insights and pride, perhaps though talking about the work at meetings or Council fora.
Acknowledging Iwi concerns or incorporating Te Ao Māori perspectives	
While the concept of balance and inter-connectedness are an important part of a Te Ao Māori worldview, the ways that these were applied in system mapping did not represent this concept very well.	Consider a parallel system mapping approach or other suitable tool specifically from a Te Ao Māori perspective, to build into the process the potential to explore aspects of co-governance discrepancies that eminent from differing world-views.
Although the System map revealed interrelationships between seemingly unrelated factors, it was acknowledged that this was developed without reference to a Te Ao Māori perspective on the relationships being discussed. This raised the potential for questions regarding how a system map populated from a Te Ao Māori perspective might differ from the one developed in this project.	

Lessons learned	Reflections for future application
Concerns that iwi/hapū involvement in non-statutory participatory processes might result in future limitations on their co-governance role. However, no agents of those present within HBMaC had been designated decision making powers by their respective agencies.	Acknowledge and address concerns of iwi/hapū about perception that involvement in participatory processes might limit future co-governance roles. Consider a Memorandum of Understanding or Terms of Reference that clearly reflects that participant opinions do not supersede individual decision-making requirements for each organisation.
Project or case study process improvements	
HBMaC was formed before the Sustainable Seas Challenge became involved in this case study, which meant the social scientific tools from Phase 1 the Sustainable Seas designed for earlier stages of the process of engagement couldn't be applied to design this participatory process..	The HBMaC stakeholder group broadly followed the principles described in the social science outputs from Phase 1 of the Challenge during its development, noting that it was formed prior to the involvement of the Challenge in this case study. Similarly, the principles of system mapping also are aligned with those highlighted in social scientific research during Phase 1 of the Challenge.
Multiple iterations of the scenarios developed by HBMaC could further explore interventions, and enhance the process.	Resource constraints within the project team limited this process to only one iteration of the HBMaC-developed scenarios. Participants suggested that additional iterations of scenarios could provide further discussion of more specific flow-on impacts of varying different parameters in the models.
Delays in project deliverables and reviews due to competing work programmes in the project team.	Projects of this length, complexity and investment could benefit from a dedicated project manager to avoid competing demands from existing work programmes.
Trust is imperative to co-developed processes, and it is difficult to put a timeframe on developing trust - in the process, in the team, and in the outcomes. Resourcing is necessary to engage with the group throughout the project to keep participants actively involved and engaged. Otherwise, participants start to lose sight of value in project and are less likely to participate in the project.	Consider greater resourcing to allow flexibility in contract processes, milestones, and deliverables.
Feedback to Sustainable Seas for other case study projects	
The nature of contracted milestones, reporting and subcontracting makes projects less flexible and not conducive to the nature of participatory processes. Co-development and engagement in participatory processes takes time and requires flexibility (of both the process and the outcome) that is often difficult to integrate into contracts. Delays in contracting processes leads to disengagement from participants. Subsequent workshop time is spent catching participants up on where the project was, at the expense of time spent moving forward.	Consider greater ability to allow flexibility in contract processes, milestones and deliverables. Consider instituting reporting requirements via informal catch ups between the project team and Challenge Leadership/Management to allow the proactive and pre-emptive identification of challenges and their resolution.
The pandemic required flexibility and willingness to engage virtually, but the project team and participants recognise that kanohi ki te kanohi (face to face) is	The additional logistics required for switching to an online environment are significant. These should be able to be recognised in the allocation of resources

Lessons learned	Reflections for future application
preferred to maximise relationship building, trust, interactions and discussion in participatory frameworks. Because HBMaC has a large amount of social capital from working together for many years, virtual meetings were still able to progress the project outcomes.	to support the projects. Consider greater ability to allow flexibility in contract processes, milestones, and deliverables.
The project team experienced logistical challenges in successfully bringing the project together and to completion. This impacted the overall timeframe of delivery and the experiences and perceptions of participants. These challenges highlighted not only the time and resources, but also the variety of skills, required to bring novel multi-method research projects to successful completion.	Consider greater ability to allow flexibility in contract processes, milestones and deliverables. Consider instituting reporting requirements via informal catch ups between the project team and Challenge Leadership/Management to allow the proactive and pre-emptive identification of challenges and their resolution.

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Connolly JD, Lundquist CJ, Madarasz-Smith A & Shanahan R (2020). Hawke's Bay EBM case study - Part 1: System mapping to understand increased sedimentation and loss of benthic structure in the Hawke's Bay. A report for the Sustainable Seas National Science Challenge. Hamilton, New Zealand: Deliberate. 94 p.

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