National SCIENCE Challenges

SUSTAINABLE SEAS

Ko ngā moana whakauka

Hawke's Bay EBM case study - Part 1

System mapping to understand increased sedimentation and loss of benthic structure in the Hawke's Bay

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Glossary of terms

Term	Description
ADCP	Acoustic Doppler Current Profiler
CRI	Crown Research Institute
DHB	District Health Board
FINZ	Fisheries Inshore New Zealand
Fisheries NZ	Fisheries New Zealand. Previously part of the Ministry of Fisheries, now part of the Ministry for Primary Industries. (See also MPI)
FMA	FMA 2 Fishing Management Area. The central east area is East Cape to Wellington. This is the management area for finfish and shellfish.
Hapū	Divisions of Māori iwi (tribes), determined by genealogical descent, usually consisting of a number of extended family groups.
HAWQi	**HA**wke's Bay **W**ater **Q**uality **i**nformation
HBRC	Hawke's Bay Regional Council
HDC	Hastings District Council
Hui	A formal or informal gathering or workshop, typically used in New Zealand to refer to Māori gatherings.
Iwi	Extended kinship group, tribe, nation, people, nationality, race - often refers to a large group of people descended from a common ancestor and associated with a distinct territory.
Kai/ kaimoana	Kai is food or the act of eating. Kaimoana is food from the sea, so specifically seafood.
Kaitiaki	A person, group or being that acts as a carer, guardian, protector and conserver.
Kaitiakitanga	The intergenerational exercise of customary custodianship, in a manner that incorporates spiritual matters, by those who hold mana whenua/moana status for a particular area or resource.
LCDB	The Land Cover Database (LCDB) offers environment data held by Landcare Research for re-use in GIS and other applications that can handle geospatial data for mapping, querying and spatial analyses.
Mahinga kai	Indigenous species that have traditionally been used as food, tools, or other resources.
Mana	Prestige, authority, control, power, influence, status, spiritual power, charisma - mana is a supernatural force in a person, place or object.
Mana whenua	The territorial rights, power from the land, authority or jurisdiction over land, territory or resource held by those that occupy tribal lands.
Manāki/ Manākitanga	Manāki: to show respect, generosity and care for others by supporting, take care of, or give hospitality to. Manākitanga : The process of the above.
Mātauranga/ Mātauranga Māori	Complex and dynamic knowledge system originating from Māori ancestors, informed by intergenerational cues, practices and understandings of the natural world.
MPI / Fisheries NZ	Ministry for Primary Industries (See also Fisheries NZ)
MWLR	Manaaki Whenua | Landcare Research

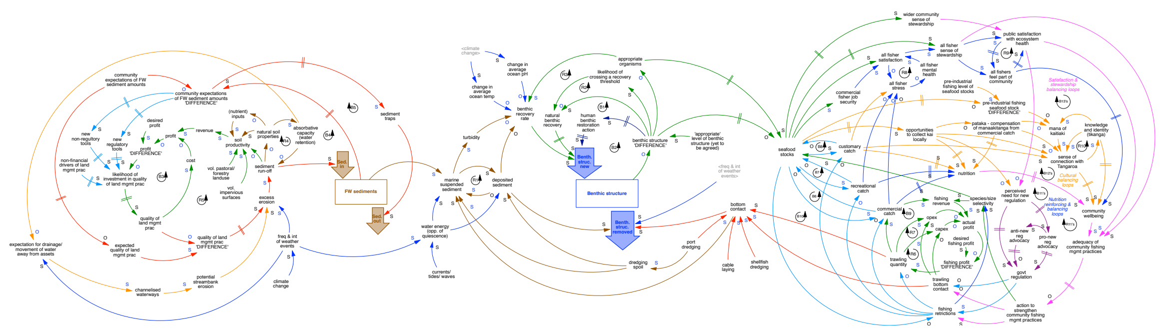
NCC	Napier City Council
NIWA	National Institute for Water and Atmospheric Research
NSC	National Science Challenge
NZPI	New Zealand Planning Institute
OLW	Our Land and Water National Science Challenge
Option4	Option4 is an advocacy group that aims to ensure recreational fishers have priority over licensed commercial fishers, limit commercial methods that deplete recreationally important areas, and stop licensing of recreational fishers. http://www.option4.co.nz/option4/who.htm
Pātaka	The general use of this word relates to a store or storehouse of or for food. In this report, the use of this term has a more specific meaning, which is the substitution of kaimoana usually collected under customary rights within the QMS, with kaimoana caught as part of commercial quota by Iwi controlled fishing interests.
Rohe	Territory or boundaries of iwi.
ROV	Remote operated vehicle
S-Map	S-map is a digital soil spatial information system for New Zealand. Product of Manaaki Whenua | Landcare Research.
SedNet	A spatially distributed, time-averaged model that routes sediment through the river network using a sediment budgeting approach. Product of Manaaki Whenua | Landcare Research.
SOE	State of the Environment [reporting]
Tangaroa	Atua (god) of the sea and fish. He was one of the offspring of Rangi-nui and Papa-tū-ā-nuku and fled to the sea when his parents were separated. Sometimes known as Tangaroa-whaiariki.
Tikanga Māori	The customary system of Māori values and practices or set of protocols that have developed over time and are deeply embedded in the social context.
TLA	Territorial Local Authority
Whānau	Family, immediate or wider.
Whanaungatanga/ Whakawhanaungatanga	Process of establishing relationships, relating well to others.
WWF	World Wildlife Fund

Executive Summary

Major challenges face the marine environment both internationally and in New Zealand. The Hawke's Bay is no exception. The fact that a non-statutory multi-stakeholder group (Hawke's Bay Marine and Coastal group (HBMaC)) was established with the assistance of the Hawke's Bay Regional Council (HBRC) several years ago, indicates the extent to which broad stakeholder support for initiatives in the marine space are required. In this research, the Sustainable Seas National Science Challenge (the Challenge) works directly with this group and their sponsor, at the heart of a case study to explore the enabling of Ecosystem Based Management (EBM) in Hawke's Bay.

Work in the first year of this two year case study has developed a conceptual system map, which demonstrates the interlinked influences of two main environmental stressors – freshwater sediments and disturbance of the seabed. See Figure 1 for an overview of what this looks like (although refer to the appendices of the report for a more readable version). This map provides a framework for working with multiple stakeholders and various knowledge sources to develop insight about how to deal with the causes and influencers of these stressors; what sorts of actions or interventions might prove the most useful; and who is best placed to take (or already has) responsibility for these. The second year of this case study will explore this in more detail.

Figure 1.Overview image of the system map developed by the HBMaC group (for context only)



Many known knowledge sources were identified and their quality estimated using a qualitative scale. This will help to guide further research investment and is also intended to guide the pragmatic use of knowledge in conjunction with the system map for any future decision-making. This 'knowledge stocktake' in particular should be considered a live document, as new knowledge will inevitably be added or updated.

This work has resulted in a solid base of conceptual knowledge about the system being dealt with, and a strong base of social capital and trust within the HBMaC group. There will never be perfect or comprehensive information required to underpin the many difficult decisions required to enable EBM. Yet there is a belief that the process to date will enable the case study and those involved, to progress into the second year with confidence, exploring potential scenarios and interventions in the system from a strong yet unavoidably incomplete knowledge base.

1. Introduction

This report summarises case study work undertaken by the Sustainable Seas National Science Challenge (the Challenge) with the Hawke's Bay Marine and Coastal Group (HBMaC Group). This research was undertaken as part of Phase 2 of the Challenge (2019-2024), after an initial Phase 1 of research (2014-2018). The case study itself is being undertaken in at least two parts, and this report summarises and describes the process and outputs from part 1.

Section 1 provides a background to the Challenge, the Hawke's Bay case study and the HBMaC group in the balance of this introduction. This describes how the case study came about; how it explores the application of decision-making tools developed in Phase 1 of the Challenge in an ecosystem-based management environment; and how system mapping is used here as a core methodological approach to achieve this. Section 2 provides a brief summary of what systems thinking is, while section 3 provides an overview of how system mapping has been applied in this research. This section should be read before any of the system maps are explored in detail, as this will outline the fundamentals of how this approach works.

The focal issues that are explored in the system map are described in section 4, as is the background as to why that are the foci of this project. The resulting system map and its three main sections are then described in detail in section 5.

Having developed and described a comprehensive system mapping, section 6 outlines a variety of ways in which this this map can be used, including demonstrating an 'analogue simulation' approach that is intended to be used in future parts of this case study. Section 7 then collates and summarises a variety of knowledge sources that could inform different parts of the system map. These are rated using a qualitative scale to help give an indication of where future research and effort may be required or directed.

A summary of the report is provided in section 8, while a detailed description of the factors described within the system map is provided in an appendix.

2. Background

The case study that this report summarises forms part of the Sustainable Seas National Science Challenge. This section outlines the background to the Challenge; describes the Hawke's Bay case study; and provides detail about the HBMaC group.

2.1. The 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 and competing uses for them, demands on them, 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 supports research within multiple case studies to inform and enable EBM approaches to decision-making through partnerships with interested regional or central government agencies. These case studies will establish proof of concept of EBM approaches, and provide key lessons about putting theory into practice to further enable EBM in Aotearoa NZ.

2.2. Hawke's Bay case study

The Hawke's Bay case study has been 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 Phase 1 of the Challenge research. The case study was initiated following discussions with the Hawke's Bay Regional Council, and with the Hawke's Bay Marine and Coastal Group (a non-statutory multi-stakeholder group, see section 2.3 for more details). Co-development partners agreed upon a primary objective of examining the impacts of overlapping stressors in the Hawke's Bay, with particular focus on sediments and seafloor disturbance from bottom fishing impacts which were perceived as the key drivers of habitat degradation in the coastal Hawke's Bay.

Sediment deposition from land-based impacts and disturbance to the seafloor have been identified as key stressors to the Hawke's Bay marine ecosystem. These multiple stressors are likely to be acting both singularly and in combination, and the cumulative impact of these stressors and their interactions on the Hawke's Bay coastal marine environment and the values held for it are unclear.

Management of these effects is complex, with different statutory agencies exerting different roles. As such, an imperative part of this project is identifying management options that could be used to reconcile these multiple impacts, facilitating decisions of which interventions (and where to implement them) will result in the best management outcomes. One tool to bring together these aspects of EBM is to develop a conceptual map (the system map described in this report) of the known stressors and impacts and how they are connected and interact, and to connect these stressors through to potential levers or policy actions. System mapping can also be used to identify who is responsible for managing these stressors, and what is actionable within current legislation, policy and practice, to assist in prioritising further work within the proposal.

The two year Hawke's Bay case study project is structured in two parts.

1. The objective of the first year of this case study project (2019-2020 – summarised in this report) is to develop a conceptual map of stressors and their impacts and importance to reversing environmental degradation in the Hawke's Bay marine environment. This will facilitate a longer-term objective of identification of mechanisms and levers to inform critical levels of these stressors, their interactions, and adapting tools from Phase 1 of the Challenge to identify and prioritise potential management or policy options. Scientific and mātauranga knowledge have been used to populate a conceptual systems model, identify knowledge gaps, and develop scenarios to evaluate and prioritise management and policy options.
2. In the second year (2020-2021), this systems map will then be used to prioritise activities in year 2 that will facilitate a longer-term objective of identification of mechanisms and levers to inform critical levels of these stressors and their interactions. Within the second part of the project, co-development partners in HBMaC will use the system mapping exercise to identify and prioritise further research that will enable implementation of EBM in the Hawke's Bay. Research that will be recommended to underpin future management is anticipated to provide information on the relative and cumulative roles of sedimentation and seafloor disturbance from fishing.

2.3. The Hawke's Bay Marine and Coastal Group (HBMaC)

The Hawke's Bay Marine and Coastal Group (HBMaC) is a multi-stakeholder group with representation from government agencies, mana whenua, recreational and commercial fishing interests. It was established in 2016 (independently of the Challenge) due to concerns over the perceived localised depletion of inshore finfish stocks and environmental degradation in the Hawke's Bay marine area. HBMaC and partners at HBRC have highlighted that there is general consensus that there has been a degradation of the marine environment of Hawke's Bay, however the scale, direction and underlying causes of this change are unclear.

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 is envisioned to assist in determining a suite of potential options that could be actioned to address ecosystem degradation, restore ecosystem health and the enhance resource utilisation of the Hawke's Bay marine ecosystem.

Members of HBMaC are supported by their parent organisations to be part of this collaborative process, which will develop recommendations to support the vision of HBMaC. At the same time, thoughts and opinions contributed as part of this group, in no way undermine the decision-making mandate and processes that need to occur at each of the organisations represented.

2.4. Acknowledging concerns from Iwi

This process has been carried out and the system map has been developed, with the broad support of the Māori and Iwi participants who were involved.

At the same time, it is acknowledged that this case study project is being carried out within a complex New Zealand landscape of assorted – and inter-connected – natural and social issues. Many of these may be the subject of research within other National Science Challenges; or the subject of work being done by any multitude of stakeholders within New Zealand, such as Iwi, central and local government, and Crown Research Institutes or Universities to name but a few. Intuitively most people know that many of these issues are inter-connected and influence each other in different ways.

The nature of how government and research institutions have evolved in New Zealand means that they tend to work in different areas of either subject matter expertise or legislative responsibility. While cooperation and collaboration across such boundaries is common, it would be fair to suggest that individual organisations are unlikely to be driven by keeping the 'entire picture' in mind – as much as they may appreciate that larger picture – and are certainly unlikely to be legislatively or organisationally driven to keep this at the forefront of their work. For this reason, Ecosystem-Based Management (EBM) has been proposed.

In contrast, Māori and Iwi hold a strong inter-connected view of the natural, human and metaphysical worlds at the forefront of their approach to any discussion about natural and/or social issues. This remains the case in the discussions that have informed the development of this system map. As a consequence, some discomfort was expressed by Māori participants about the potential exclusion or misrepresentation of important Māori concepts in the resulting system map.

Although the development of this system map was undertaken in collaboration with representatives of mana whenua, it must be acknowledged that a map developed purely from a Te Aō Māori worldview may be different and distinct from a map developed from combined Western/non-Māori and Te Aō Māori worldviews, as this one has been.

In addition, it is also noted that there are other issues in the wider landscape of assorted issues being dealt with in New Zealand (as mentioned earlier), that remain of high concern and priority to Iwi Māori. In particular, there remain ongoing discussions and processes involving various potential or actual Te Tiriti o Waitangi settlements or legal processes that may clarify or determine various property rights of Iwi in the future. Some Iwi Māori want to ensure that involvement in this process will not impact on the outcome of any of those such processes.

All of these such processes are beyond the scope of both the Sustainable Seas National Science Challenge; and the remit of the HBMaC Group. It is not the intention of any words or concepts used in this system map process to influence any of these other processes.

Therefore, while this map is the result of a combination of these worldviews it does not supersede the distinct perspectives and decision making processes of Ngāti Kahungunu whānau, hapū, iwi. Upholding respective Te Tiriti rights and interests of whānau, hapū, iwi mai Paritu ki Turakirae is of paramount importance.

3. What is systems thinking?

The world that we live in is a highly interconnected place of causality and effect. The work of policy development often seeks to respond to undesirable behaviour or patterns being experienced in our natural environment and therefore seeks to influence these causes, to alter or improve the desired behaviour.

'Systems Thinking' is a name often applied to a range of approaches to thinking about issues holistically. One of these approaches is academic discipline of 'System Dynamics'. System Dynamics originated from the Sloan School of Management at the Massachusetts Institute of Technology, Cambridge, Massachusetts in the late 1960's.

Systems thinking, as articulated by the discipline of System Dynamics, is a conceptual framework and set of tools that have been developed to help make these patterns of interconnectedness clearer (Senge, 2006)[1]. They help us understand the structure of a set of various interacting factors that create a behaviour that we are trying to understand. Once these interconnections are articulated, we can better understand which parts of a system are having the most influence on the behaviour, allowing us to identify areas of leverage in order to influence this.

Where the term systems thinking has been here, it refers to the qualitative concepts articulated by the discipline of System Dynamics (Sterman, 2000). The main qualitative tool that this discipline uses to understanding systems is called a causal loop diagram (CLD) or a system map. Throughout this report the term 'system map' has been used.[2]

4. The fundamentals of system maps – articulating system structure

At the core of a system map is the desire to visually articulate the relationships between variables that best explain the behaviour of the system that you are trying to understand. This visual articulation of relationship is known as 'system structure'.

This section outlines important fundamental elements of system structure. These are:

- feedback loops;
- how feedback loops are correctly annotated; and
- the use of the 'goal/gap' structure (as this can explain how different loops dominant in a system at different times).

It is recommended that the reader familiarises themselves with these concepts, as an understanding of them is required to read the system maps in this report and gain insight from them.

[1] For a detailed introduction to the concepts of Systems Thinking, the reader is referred to *The Fifth Discipline – the art and practice of the learning organisation* (2nd ed.) by Peter Senge (2006) as an accessible introduction.

[2] System maps have also been used in several other pieces of research within the Challenge. It should be noted that while the methodology has been the same in all cases, in some instances a different name may have been used. For example, in this report; the initial pilot in Tasman Bay and Golden Bay (Connolly, J. (2019). *Piloting the use of System mapping in the Sustainable Seas National Science Challenge*. (A report for the Sustainable Seas National Science Challenge). Hamilton, New Zealand: Deliberate); and a report on the Blue Economy (Connolly, J.D. & Lewis, N.I. (2019). *Sustainable Seas National Science Challenge: Conceptual systems maps of 'Blue economy' activities*. (A report for the University of Auckland). Hamilton, New Zealand: Deliberate), the term *'System mapping'* has been used. In a report on the application of system mapping to Te Ao Māori perspectives (in print), the term *'Causal mapping'* has been used.

4.1. Feedback loops – the basic building blocks of a system map

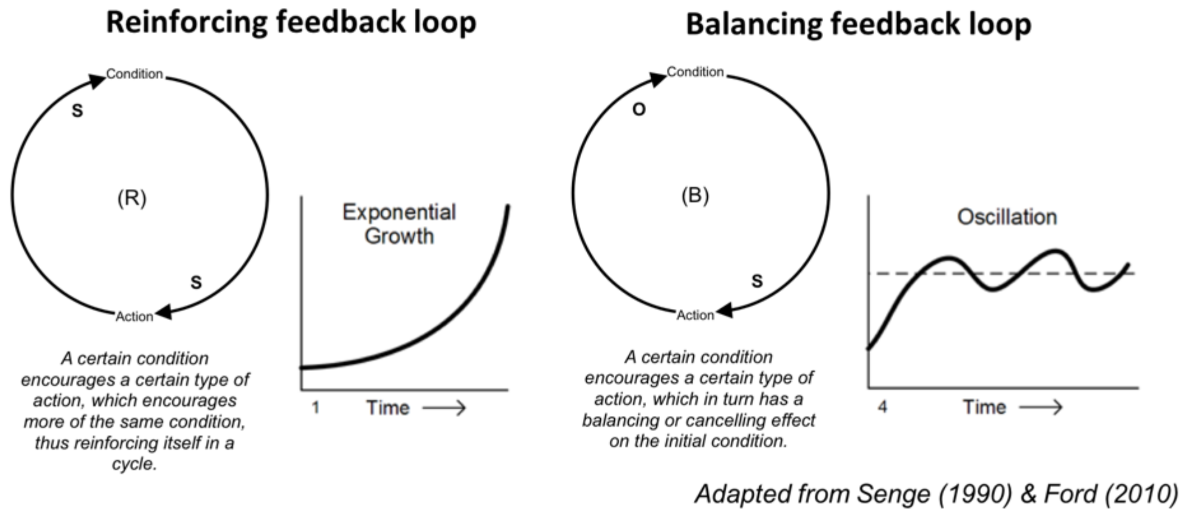
Systems thinking is especially interested in systems where loops of causality are identified – these are called *feedback loops*. There are two types of feedback loops, *reinforcing* and *balancing* (Senge, 1990).

In a *reinforcing feedback loop*, the direction of influence provided by one factor to another will transfer around the loop and influence back on the originating factor in the *same* direction. This has the effect of *reinforcing* the direction of the original influence, and any change will build on itself and amplify. ***Reinforcing loops are what drive growth or decline within a system****.*

In a *balancing feedback loop*, the direction of influence provided by one factor to another will transfer around the loop through that one factor (or series of factors) and influence back on the originating factor in the *opposite* direction. This has the effect of *balancing out* the direction of the original influence. **Balancing loops are what create *control, restraint or resistance* within a system**.

The two types of feedback loop are described in Figure 2.

Figure 2.The two types of feedback loops



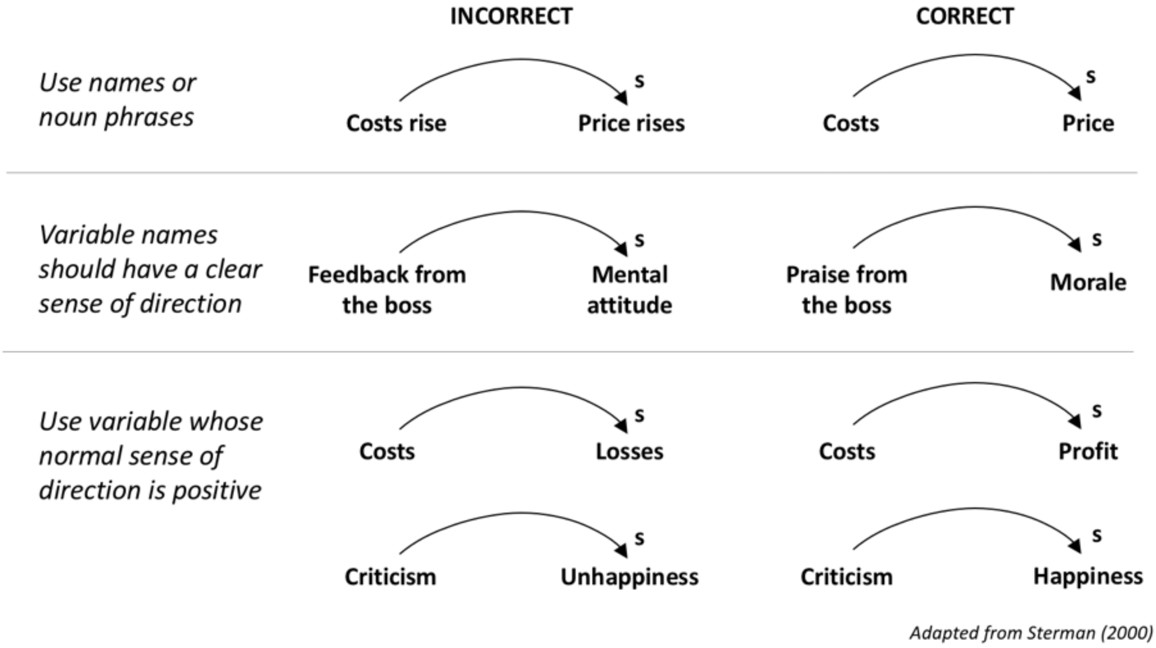
Feedback loops can be made up of more than two variables and can be mapped together to form a system map). How these interact provide insight into how a wider system operates.

4.2. Labelling variables

An important concept within system maps is the concept of accumulation (or decumulation) –where do things build-up (or decrease) in your system? The simple analogy of a bathtub is often used to describe this (for more on this see section 4.5).

In system maps, this concept of accumulation is captured by describing variables in such a way that their name implies that they can *increase or decrease*. This means that they should be described as *nouns*; have a clear sense of *direction*; and have a normal sense of direction that is *positive*. Examples to demonstrate this are shown in Figure 3.

Figure 3.Labelling variables

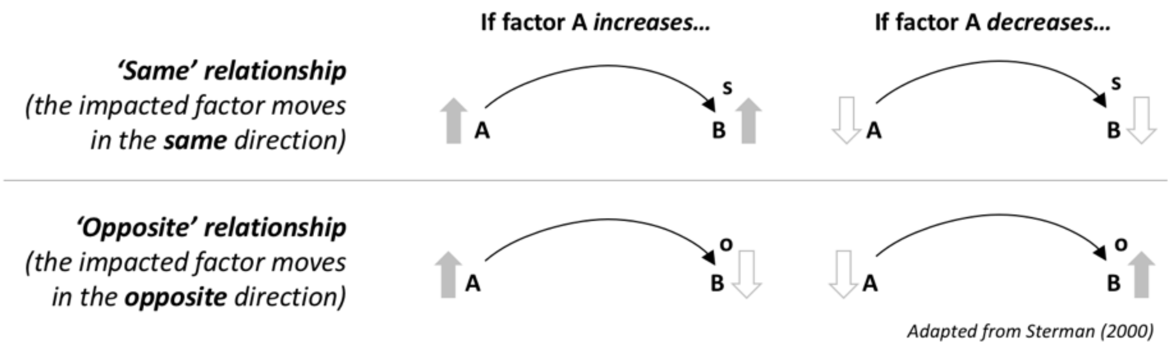


4.3. Annotating loops

Variables within system maps are connected (and made into feedback loops) by arrows, which indicate that one factor has a causal relationship with the next. These arrows are annotated with either an **'s'** or an **'o'** which stands for **'same'** or **'opposite'**. These terms correspond to the direction of change that any change in the first variable will have on the second variable.

For example, if a directional change in one variable leads to a directional change in the next variable in the *same direction*, it is a *same relationship*. Likewise, if the second variable changes in the *opposite direction*, it is an *opposite relationship*. See Figure 4 for a visual description.

Figure 4.How arrows are labelled in system maps



If there is a notable *delay* in this influence presenting in the second variable, when compared to the other influences described in the system map, this is annotated as a *double line crossing the arrow*. An example of this is shown in Figure 5.

Figure 5. How delays are annotated on arrows

4.4. Goals and gaps – driving individual loop dominance.

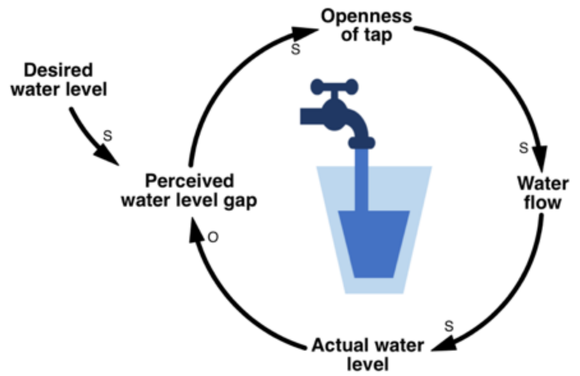
Realising that multiple loops are operating within a system is the first useful insight of systems thinking. A further useful insight is understanding that not all loops operate at the same strength all of the time. Different loops can dominate the dynamics of a system at different times. For example, a system might be dominated by a period of growth (a reinforcing loop), but when some kind of physical limit is approached (e.g. the available space in a pond for algae to grow) a balancing loop will start to dominate, therefore slowing the rate of growth.

One useful mechanism for gaining insight into the strength of a balancing loop is the *'goal/gap' structure*. This is a structure that combines both a *desired level* of something (a 'goal'), with an *actual level* of something. This *difference between these variables* is the 'gap' between the desired and actual levels.

The higher the desired level and the lower the actual level, **the greater the 'gap' or difference and the stronger the operation** of the loops that this gap influences. The lower the desired level and the higher the actual level, **the lower the 'gap' or difference, and therefore the weaker the operation** of the loops that this gap influences.

The 'goal/gap' mechanism can be seen within the system map in this report. A conceptual example is shown in Figure 6 which shows the act of filling a glass of water.

Figure 6. Example of a 'goal/gap' structure in a system map – pouring a glass of water



Adapted from Senge (1990)

Initially, while the *gap/difference* between the desired and actual water level is *high*, the tap will be opened more and the strength of the water flow is higher.

As the desired level of water is approached the *gap/difference reduces*, so the tap is closed further, weakening the flow of water (you don't want the water to overflow the glass), until it is fully closed when the water level reaches the desired amount (Senge, 1990).

4.5. Stock and flow notation

The bulk of the system maps described in this report are made up of variables and arrows as described above. Such variables are the core of system maps. However, in some places selected variables are described in a slightly more involved way – they are shown in *stock and flow notation* – which provides a slightly more nuanced level of insight to the behaviour of the system.

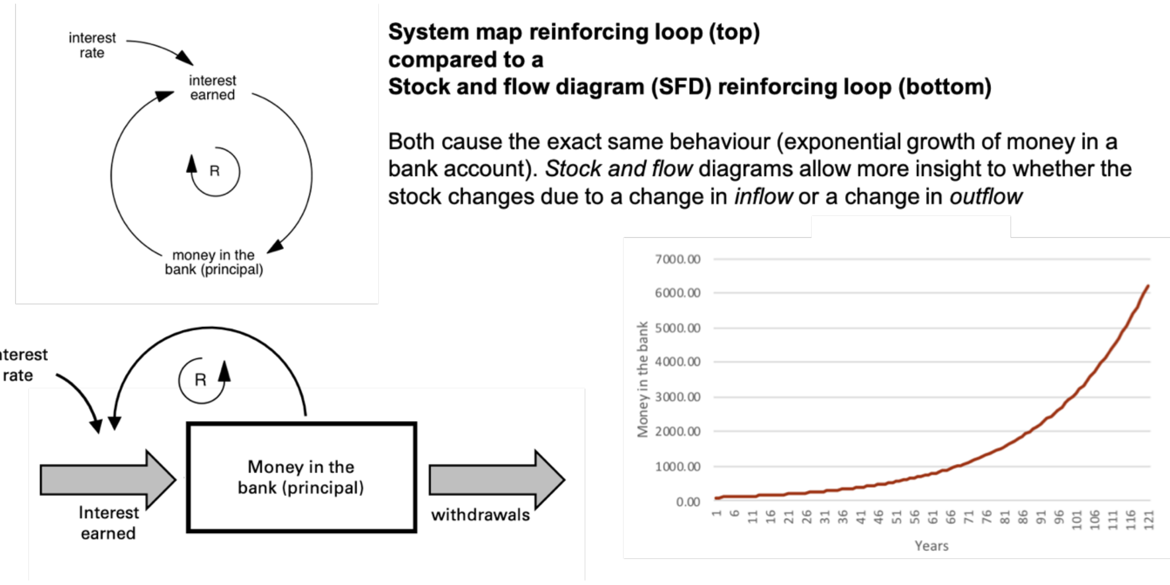
Using a stock and flow notation is similar to a metaphorical *bathtub* (as mentioned earlier). A stock might be anything that we are interested in – number of people, quality of water, level of morale, etc. **Stocks can ONLY increase through more inflow** (the tap over the metaphorical bathtub), **and ONLY decrease through more outflow** (the drain in the metaphorical bathtub), for whatever you are interested in – just like the level of water in a bathtub. This is reflected in the diagrammatic description of a stock and flow (Figure 7).

Figure 7.Stocks and flows – the more advanced notations used in System Dynamics

Both basic system maps and more complicated stocks and flow diagrams explain the same type of behaviour. Yet the inclusion of stock and flow notation within a system map allows a greater level of insight to understand whether a change in a key variable (stock) is due to a change in *inflow* or a change in *outflow* (see Figure 8 for an example).

In this report, the use of stock and flow notation has been included for the underpinning central variables of *sedimentation* and *benthic structure*.

Figure 8.Comparison of reinforcing loops: System maps (causal-loop diagrams) vs. Stock and flow diagrams



Stocks and flows are the language of simulation modelling in System Dynamics. If any of these diagrams were to be developed into quantitative simulation modelling (in potential future research), then full stock and flow formulation would need to be used. This spectrum of complexity within the tools of System Dynamics is explained in the next section.

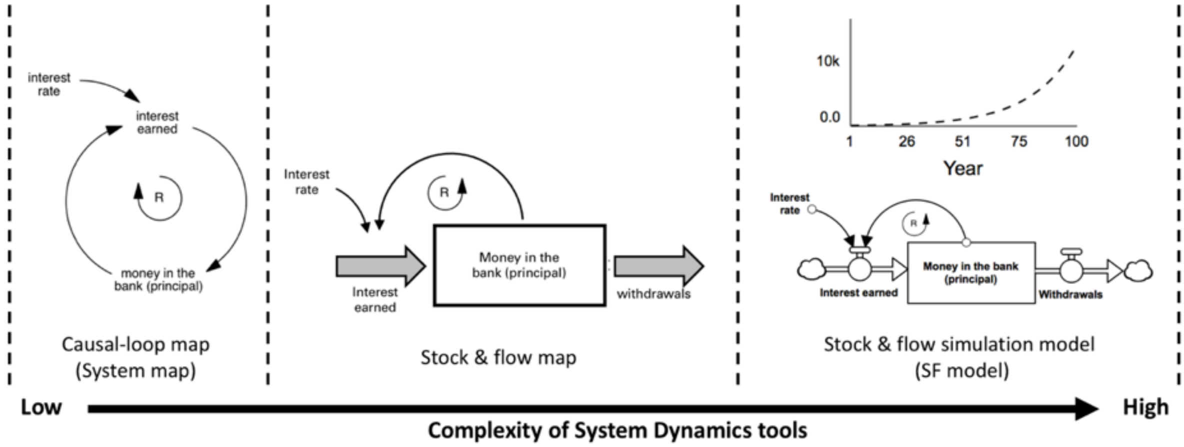
4.6. How system maps can be used

This section briefly outlines how system maps themselves fit within a spectrum of complexity in the discipline of System Dynamics, and how they may be used in conjunction with other methodological approaches.

4.6.1. System maps on the spectrum of complexity within System Dynamics

The tools of System Dynamics themselves exist on a spectrum of complexity. These are shown in Figure 9 which highlights how these varying tools can demonstrate the same system, and to make the point that system maps are not the only possible output from the use of SD tools.

Figure 9.System Dynamics tools exist on a spectrum - System maps (or Causal loop diagrams), Stock and flow diagrams, and Simulation modelling.



System maps as developed here, exist at the conceptual (low complexity) end of this spectrum. These can range from using the simple dynamics of a single feedback loop to demonstrate a type of behaviour, to multiple loop systems (as in this report) – which themselves can be reasonably complex.

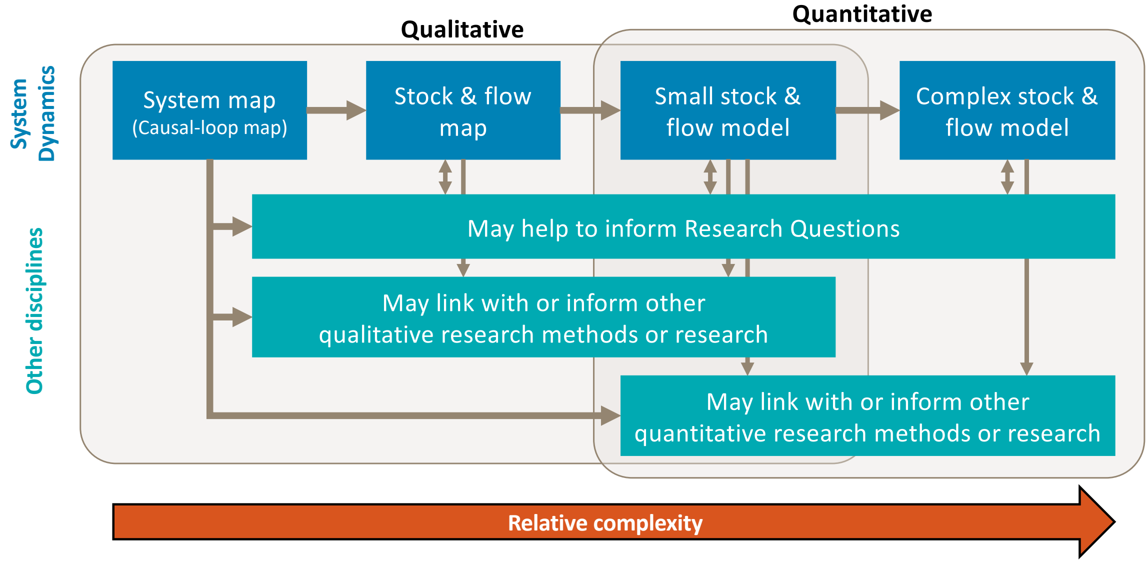
The next step up in complexity are Stock and Flow Diagrams (SFD). While *Freshwater sedimentation* and *Benthic structure* are represented in the maps within this report using stock and flow notation, these maps are not considered complete of 'full' SFD. This is because SFD usually contain multiple stocks of interest, not just the focal variables. Although not all factors need to be stocks, their architecture tends to represent a greater level of mathematical functionality. This is because SFD tend to be qualitative representations of the actual functions and equations that would be represented in a stock and flow model. This level of detail has not been achieved in this report.

Computer simulation modelling (based on the stock and flow formulation) is the next step in complexity – that is, actually turning stock and flow diagrams into simulation models. There is huge variability in the types of simulation models that can be developed, with some people advocating that large system insights can be gained from using small scale models (Meadows, 2008), to others demonstrating the utility of large scale and highly complex simulation models (Sterman, 2000).

4.6.2. How system maps may link with other methodological approaches

While system mapping may lead to more complex stock and flow diagrams and simulation modelling within System Dynamics, it may also link with or inform other methodological approaches within a wider research project. A diagram outlining how this can work is shown below in Figure 10.

Figure 10. How system mapping can link with other research methodologies



Note: There is an overlap of the qualitative and quantitative areas of application because they are not mutually exclusive. For example, some quantitative relationships in models and their calculations may be informed by research or data, while others may be informed or assumed via some form of participatory process.

The series of *blue boxes* across the top of the diagram in Figure 10 represent the increasing complexity of the System Dynamics tools. The *turquoise boxes* in the lower part of the diagram represent the research questions that may be generated in the course of research, as well as the different qualitative and quantitative methods that may be employed within the research. All of these may be informed by the system mapping process, or a more complex evolution of a system map (for example a small stock & flow model).

For example, a system map may provide insight to the nature of relationships within the system that may inform how a research question is framed. It may also inform the types of people who might be involved (as researchers or as research subjects). Further, the nature of the relationships elicited throughout the system mapping process could also inform other research methods – either qualitative or quantitative – that may be used.

Please note that while the diagram above suggests that as research becomes more quantitative it becomes more complex, that is not our intention. Rather, our position is that more precise numerical measures tend to give systems theorists the opportunity to specify more precise relationships and thus add layers of complexity to their models. In fact, in complex worlds, qualitative methods are more likely to capture complexity and make it available for analysis. In complex worlds, systems thinking and causal mapping may be used as a decision-support tool that enables a more holistic view of inter-relationships that may otherwise be missed or excluded from reductionist analyses (Senge, 2006; Pearl & Mackenzie, 2018).

5. The focus issues – freshwater sediments and benthic structure

During development of the collaborative project, the Hawke's Bay Marine and Coast group (HBMaC) meet with Challenge leaders to determine how knowledge collected throughout the life of the Challenge may be used to support Ecosystem Based Management in a real world context. The group largely agreed that land-based impacts from sediment delivery, and disturbance to the benthic structure caused by bottom trawling, were two of the key stressors contributing toward a degradation in ecosystem health. Acknowledging that additional stressors (e.g. nutrient delivery, species reduction through fishing) also contribute lower ecosystem health outcomes, it was agreed that focusing on these two dominant stressors would provide a clearer path for future management interventions.

As a result, these two issues (sedimentation and loss of benthic structure) were explored in more detail in the first workshop. This was to ensure that the group was clear what the system map would be focused on.

As a result of discussion, these two factors were refined and defined as follows:

- **Freshwater sediments:** The amount of sediments making their way into the estuarine or marine environment. This transport occurs via freshwater streams and rivers. (see section 6.1.2 for more detail)
- **Benthic structure:** The level of benthic structure in the marine environment. This was deliberately left as a generic term so that different types of benthic structure could be considered in different parts of Hawke's Bay. (see section 6.1.1 for more detail)

It is noted that where earlier meetings of the HBMaC group had described disturbance to the benthic structure due to bottom trawling, this workshop agreed to the level of benthic structure. It was felt that labelling the act of bottom trawling in one of the focus factors might predetermine the likely outcomes or recommendations from the system mapping process. This was agreed to without prejudice to any discussion regarding how much bottom trawling may be contributing to this issue.

Together, workshop participants sketched out the perceived trends of these two key variables over time. This discussion focused on the ***past*** behaviour of these variables and was a useful way of enabling participants to articulate the changes that had occurred over time, which would later be captured in the system map. Participants were also asked about ***future*** behaviours. They were asked to sketch:

a) where they thought these behaviours were likely to **trend in the future if nothing was done (BAU)**;
b) where they **feared they would trend** (regardless of intervention); and
c) where they **hoped they would trend** (regardless of intervention). The results of this exercise are shown in the figures below.

Figure 11. **Freshwater sediments: perceived historic and future (BAU; feared; and hoped for) trends**

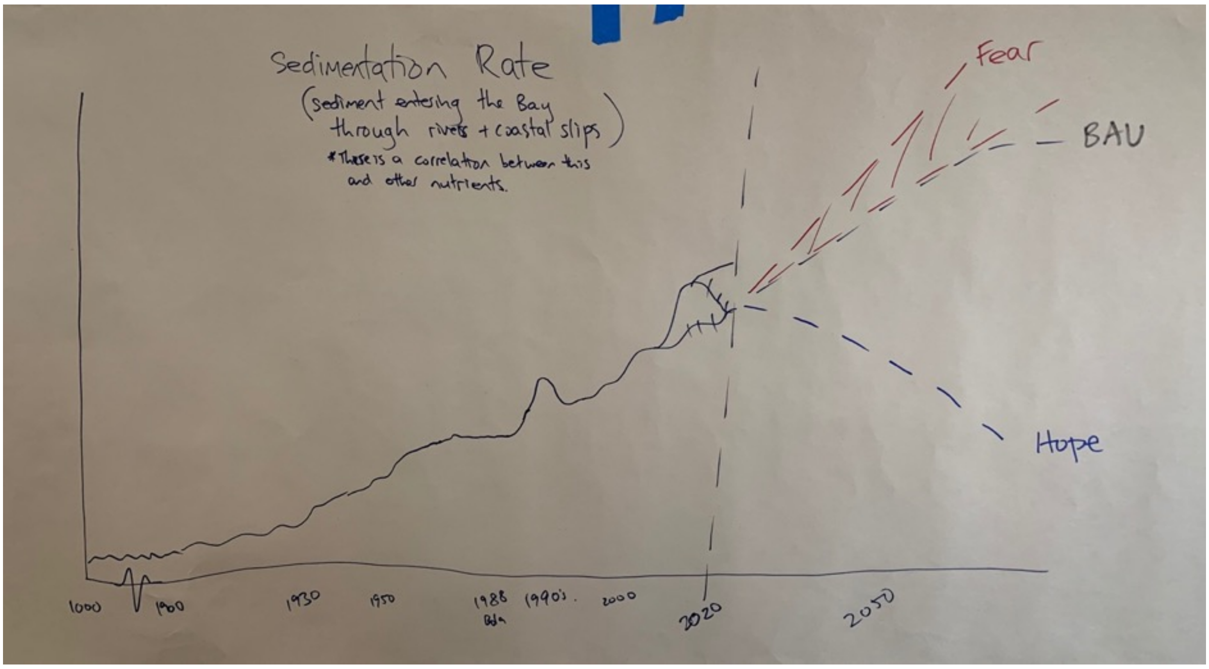
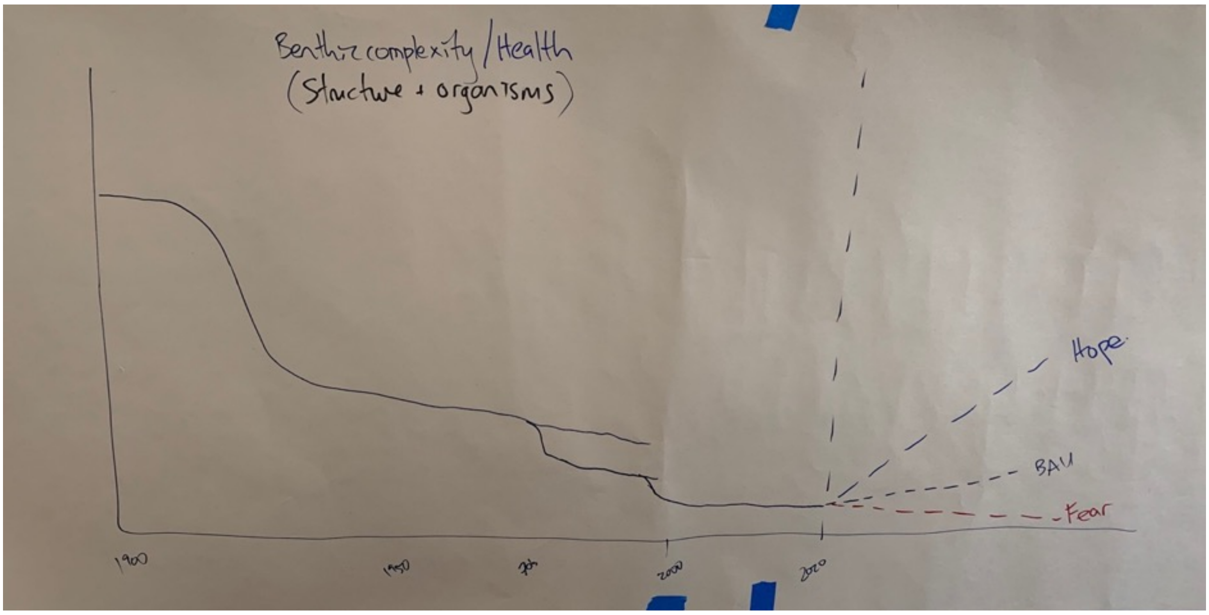


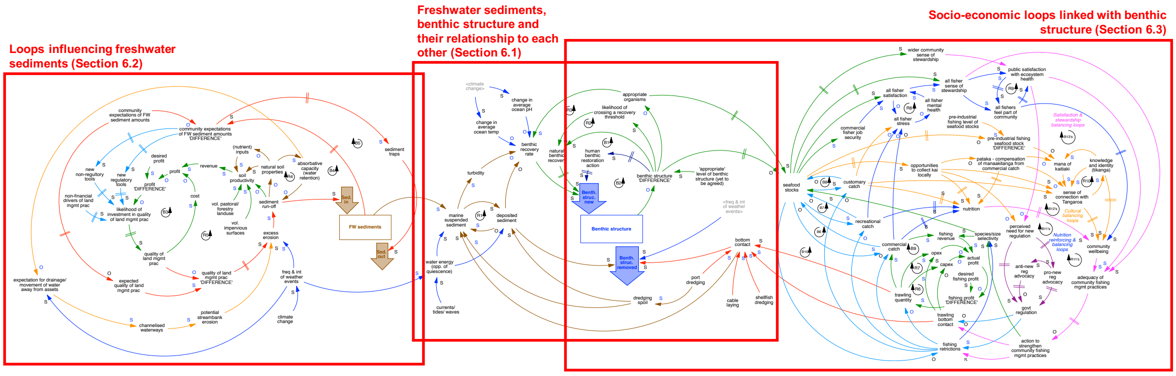
Figure 12. **Freshwater sediments: perceived historic and future (BAU; feared; and hoped for) trends**



6. Description of the system map

The following is a summary of the system map developed with members of the HBMaC group. It is made up of three main sections. These are based around the two core variables (stocks) noted above, which reflect the important two stressors that the HBMaC group agreed to focus on.

Figure 13. The three sections of the system map



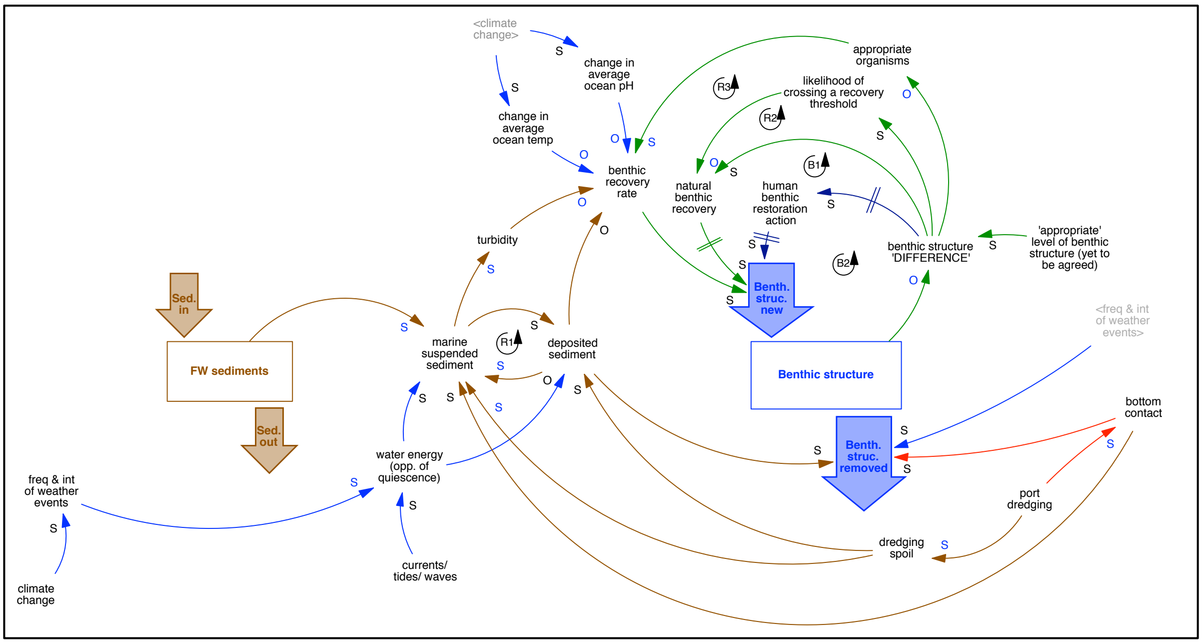
Each of the three sections is summarised here. A glossary of the terms used in the CLD is provided in the Glossary of terms. A full reproduction of the map is provided in Appendix 3.

Different colours have been used throughout the CLD to indicate where loops and influences tend to go together or operate as part of the same loop, or sector. While these provide a useful help to reading the diagram, it should be noted that many arrows form part of several loops, so the colour used is not a firm indication of the loop that the relationship is part of.

6.1. Freshwater sediments, benthic structure and their relationship to each other

This section describes the relationship between the two focus issues in the system map – Freshwater sediment load and benthic structure. The section of the overall system map, discussed here in parts, is shown in Figure 14.

Figure 14. Overview of the relationship between the two focus areas: Freshwater sediments and Benthic structure



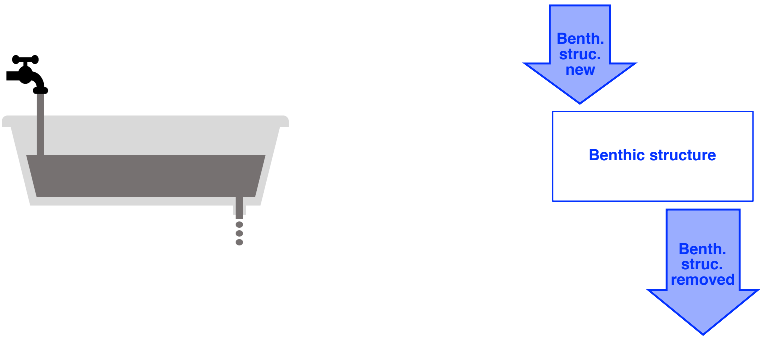
6.1.1. The benthic structure stock

The first of the two focal issues is the level of benthic structure in Hawke's Bay. This term has been used to represent any type of benthic structure that may be the focus of discussion, at a certain geographical place in Hawke's Bay. Benthic structure covers a range of benthic types: it could mean things that have no, or limited, 3D structure found above the seafloor such as soft sediments and gravel; or faunal or mineral structure such as reefs or rock structures; or even floral structures such as kelp beds. It is very important to note that the term 'benthic structure' applies to all of these and, in keeping with the intended use of this system map, specific cases may be kept in mind when discussing the dynamics of *that* system (with that specific type of benthic structure at its core) that the system map articulates.

As described earlier, the analogy of a bathtub has been used for the two focus issues. For benthic structure, this has been represented in the system map as shown in Figure 15, below.

Here, the 'bathtub' represents the amount of benthic structure being considered. The bathtub part of this image represents the amount of this structure that has 'accumulated' – in the system map this is a square. The 'tap flowing in' to the bathtub is represented by the downward facing arrow pointing *into* the square (bathtub). This represents any *new* benthic structure that is created, thus *adding to* the stock of benthic structure. The 'drain flowing out' of the bathtub is represented by the downward arrow pointing *out of* the square (bathtub). This represents any benthic structure that is *removed* from the stock of benthic structure – this could be either physically removed (e.g. trawled), removed due to some kind of influence (e.g. being smothered in sediment), or altered through natural processes.

Figure 15. The benthic structure stock

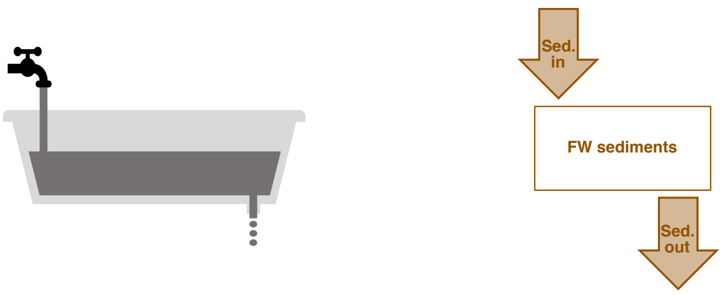


6.1.2. The freshwater sediments stock

The second of the two focal issues is the level of freshwater sediments that flow into Hawke's Bay. This is the freshwater sediment load from freshwater bodies that flows directly into Hawke's Bay. This has been represented in the system map as shown in Figure 16 below.

Here, the 'bathtub' represents the amount of sediments suspended in the freshwater body – that is, the amount of sediment that flows to the marine environment from freshwater bodies. The bathtub part of this image represents the amount of sediment suspended or 'accumulated' in the freshwater body. The 'tap flowing in' to the bathtub is represented by the downward facing arrow pointing *into* the square (bathtub). This represents any *new* sediment that makes its way into the freshwater column, thus *adding to* the amount of sediment suspended in freshwater bodies. The 'drain flowing out' of the bathtub is represented by the downward arrow pointing *out of* the square (bathtub). This represents any sediments that *settle out* from the water column and does not make it to the ocean.

Figure 16. The freshwater sediments stock



6.1.3. Where sediment goes

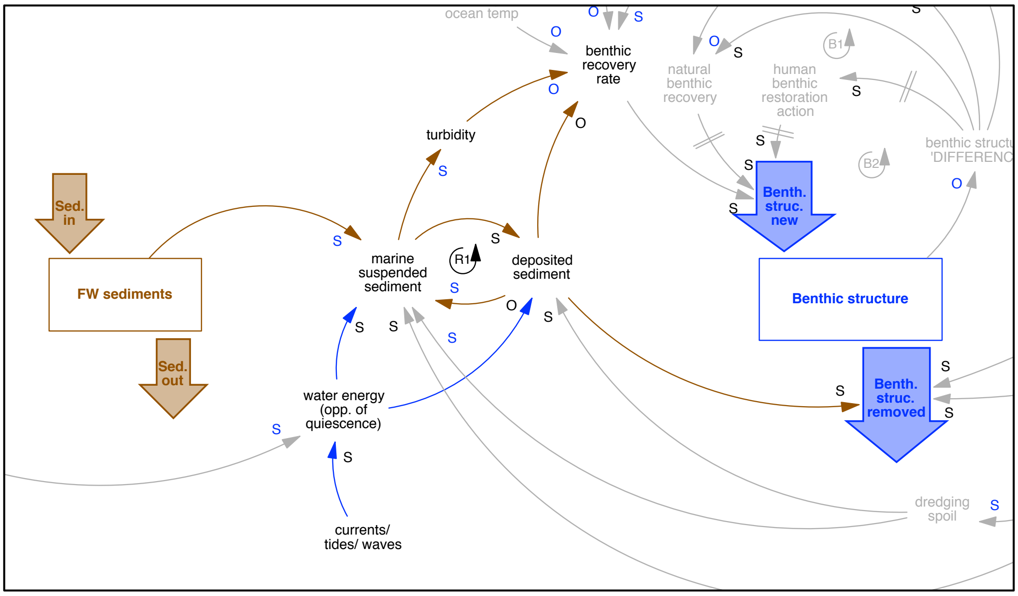
Having determined that the brown square labelled 'FW sediments' is the sediment load that reaches Hawke's Bay, where that sediment goes is highlighted in the part of the system map shown in Figure 17.

The more (or less) *FW sediments* then the more (or less) *marine suspended sediment*, which in turn increases (or decreases) *deposited sediment*. These two factors also have a reinforcing loop between them – the more (or less) of each then the more (or less) of the other (**R1**).

Further, increased (or decreased) *marine suspended sediment* will increase (or decrease) *turbidity*, which in turn may decrease (or increase) the *benthic recovery rate*. *Benthic recovery rate* as used here is a generic term to describe the natural recovery rate over time for different kinds of benthic structure. Obviously it will change depending on the benthic structure in question. It may also not be a specific rate in itself and may be made up of a range of factors. This is intended as a placeholder that can be exchanged for various factors depending on the benthic structure being considered. How this works is explained in more detail in section 6.1.4.

Deposited sediment also has an opposite relationship with *benthic recovery rate*, so the more (or less) sediment, the less (or more) the *benthic recovery rate*. It also has a same relationship with *Benthic structure removed*. So, the more (or less) *deposited sediment*, the more (or less) *Benthic structure* is removed through smothering by sediments**.**

Figure 17. Where sediment goes



6.1.4. Regeneration of benthic structure

Two main pathways for the regeneration of benthic structure were identified and are described in several loops (Figure 18 following). These were *natural benthic recovery*, and *human benthic restoration action*. Both of these pathways are linked to the goal/gap structure of the actual amount of *benthic structure*, and the *'appropriate' level of benthic structure*.

The role of goal/gap structures in explaining the strength of different loops at different times has been outlined in section 4.4. This goal/gap structure sits at the core of this system map. Here, the *benthic structure 'DIFFERENCE'* is the difference between how much structure there is (*benthic structure*), and how much is considered an appropriate amount (*'appropriate' level of benthic structure*).

It was inherent in the discussion relating to the initial seabed issue that the removal of benthic structure over time had been part of the problem. Therefore, the goal/gap structure was used here as a way of representing how the benthic structure was *out of balance* in the system people were describing. It is a good way for describing how the more out of balance something is (the further away from its 'goal'), the harder a system will push to return to that goal (or equilibrium).

The wording of the 'goal in this goal/gap structure is worth discussing. Many words were suggested to describe what the 'goal' component in this structure represents: an appropriate level; aspirational level; desired level; natural level; or even target level. All of these terms are value-laden, and it proved difficult to choose one. For example, there was not broad agreement that an area should (or even could) be returned to a 'natural' level of benthic structure.

The group had difficulty agreeing on a term that best represented the 'goal' here. In the end it was agreed that 'appropriate' would be used for the purposes of allowing the development of the system map to continue, although there remains some discomfort with that word.

The main discomfort with many of these words was that they seemed to imply that there was agreement around what the ‘target’, ‘aspirational’ or ‘appropriate’ level actually should be. It was found that the *process* of determining what this level should be, rather than what it was *called*, was indeed the challenging part. The system map is agnostic in this regard. It enables an understanding of how in (or out of) balance the actual level of structure is with what any ‘appropriate’ (or target) amount should be in the future, and what influences this difference will drive.

While the map has been developed without prejudice to whatever future level of benthic structure is sought, it may be a useful tool to help reach agreement on that level. This is because it may be used to consider variations for what an appropriate level should be and the influences and impacts that they will prompt.

This goal/gap equation is linked as the driver of the dominance of all the loops that are formed with *benthic structure*. These are now discussed.

The **natural benthic recovery pathway** represents the type of recovery that would occur naturally, after some kind of disruption (human or natural), if an ecosystem was left to recover. This does not necessarily mean that an ecosystem would return to exactly the *same* as it was before, as the type of benthic structure may change, as often happens naturally. However, this does represent the ability of the ecosystem to return to some kind of balance that would support a healthy fishery, on its own. This happens via two loops in the map:

The first is simply that a the more out of balance the benthic structure is (the greater the *difference*), then the more *natural benthic recovery* this prompts (**B1**). This eventually leads (due to a delay), to more *new benthic structure* being generated and added to the stock of *benthic structure*.

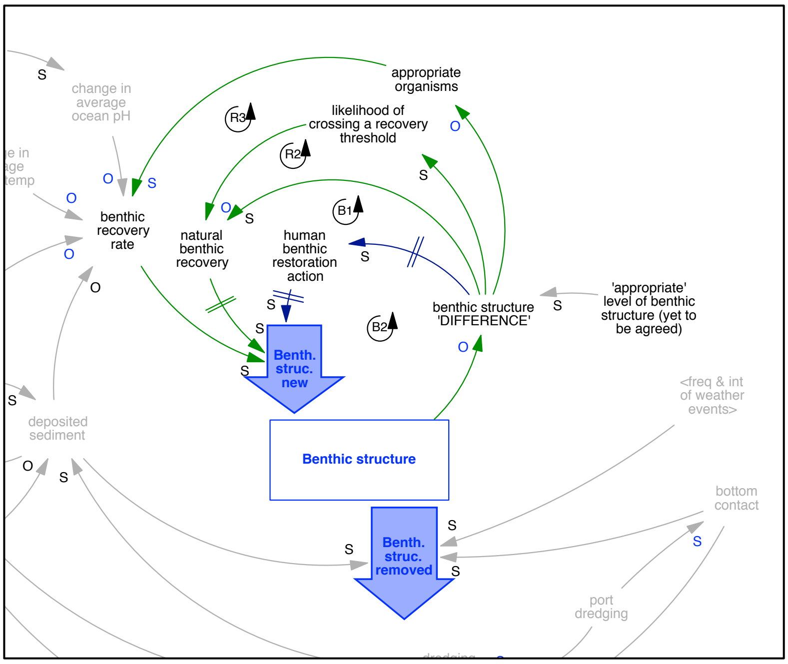
The second and loop is similar but has an additional factor of the *likelihood of crossing a recovery threshold* (**R2**). The greater the *difference*, the greater the *likelihood of crossing a recovery threshold*, leading to *less natural benthic recovery* and therefore less *new benthic structure*. As this is a reinforcing loop, it can spiral in support of recovery, if the balance is not disrupted too much, or it may flip into a vicious spiral, if the structure gets too far out of balance.

These two loops capture the dynamics of how structure can, if thrown out of balance, recover naturally, or possibly not at all if the balance is thrown out too far. As before, this structure has been designed to represent the generic pressures facing many different types of benthic structure. It is not intended to capture any one specific set of interactions or thresholds that describe any one particular ecosystem.

The **human benthic recovery pathway** represents the type of recovery that would occur if some kind of human intervention was made to help an ecosystem to recover (**B2**). Again, this does not necessarily mean that an ecosystem would be supported to return to exactly the *same* as it was before, as the type of benthic structure may change. But it does suggest an alignment between the type of benthic structure that human intervention is supporting and the ‘appropriate’ level of that structure that.

Here, if the benthic structure different becomes (or remains) too great (i.e. out of balance), the decision may be made to take some kind of human intervention to prompt benthic restoration. In time, this will generate *new benthic structure* which will increase the overall stock of *benthic structure*. This loop will operate until the amount of structure is back in balance, or the other loop of natural recovery begins to dominate more, and no further human intervention is required.

Figure 18. **Regeneration of benthic structure**



Both of these natural and human recovery pathways will be influenced by the ***benthic recovery rate***. This represents the rate at which benthic structure will recover, however that recovery is occurring. The *recovery rate* is part of a reinforcing loop with the *benthic structure 'DIFFERENCE'* and *appropriate organisms*.

Appropriate organisms is intended as a factor that describes various other fauna associated with certain types of structure. For example, with kelp forests, there are a range of other species that do not form part of the 'structure' itself, but that the kelp forest is dependent on to be a healthy ecosystem. If the *benthic structure 'DIFFERENCE'* is low, then there are still a reasonably high number of *appropriate organisms* and the *recovery rate* is not adversely affected. In effect, the recovery rate is resilient to a small amount of imbalance. As this difference increases however, less and less *appropriate organisms* remain, which in turn reduces the *benthic recovery rate*, thus reinforcing a vicious cycle. The way to tip this reinforcing loop back into a positive one is to reduce the *benthic structure 'DIFFERENCE'*.

We have already discussed how the *benthic recovery rate* is impacted by turbidity and deposited sediment. It is also impacted by other factors linked to *climate change*. These are discussed in the next section (6.1.5).

6.1.5. The impact of bottom contact on sediment and benthic structure

Having described where sediment goes and how benthic structure regenerates, this section cover the direct impact that *bottom contact* has on both these things.

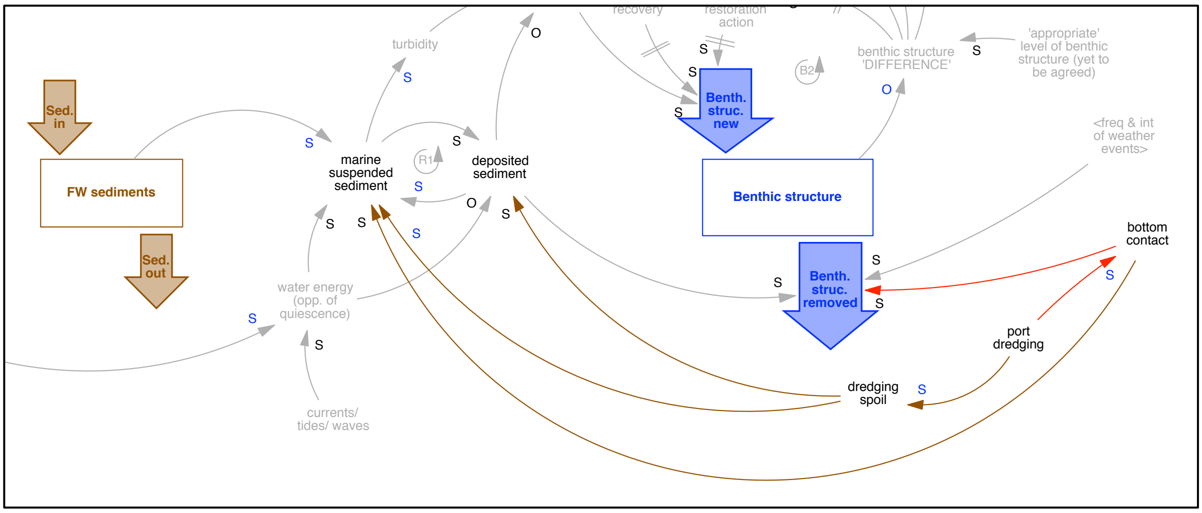
Bottom contact here describes any disturbance of the seabed through human activity. Several of these activities are described in the overall map. Only one is described here (Figure 19) – the others are described in section 6.3.

The factor described here is *port* dredging. This is because it is the only one that directly affects *benthic structure* as well as both *suspended* and *deposited sediment*.

Any increase in *bottom contact* is likely to result in benthic structure removal. The exact extent of this will depend on the type of *bottom contact* that occurs, but this structure can be used to describe any effects that may occur. *Bottom contact* also results in resuspension of sediment, therefore increasing *marine suspended sediment*.

Port dredging is itself a form of *bottom contact*, so therefore this is shown as a *same* relationship. However, the act of dredging also results in the collection of spoil which needs to be dumped somewhere. Therefore, any increase in *port dredging* will also result in an increase in *dredging spoil*. In turn, this will increase both the amount of *deposited sediment* as well as the *marine suspended sediment* as the dredging spoil passes through the water column and settles on the seabed.

Figure 19. The impact of bottom contact on sediment and benthic structure



6.1.6. The impact of climate and climate change

Climate change impacts a variety of factors in the system map (Figure 20).

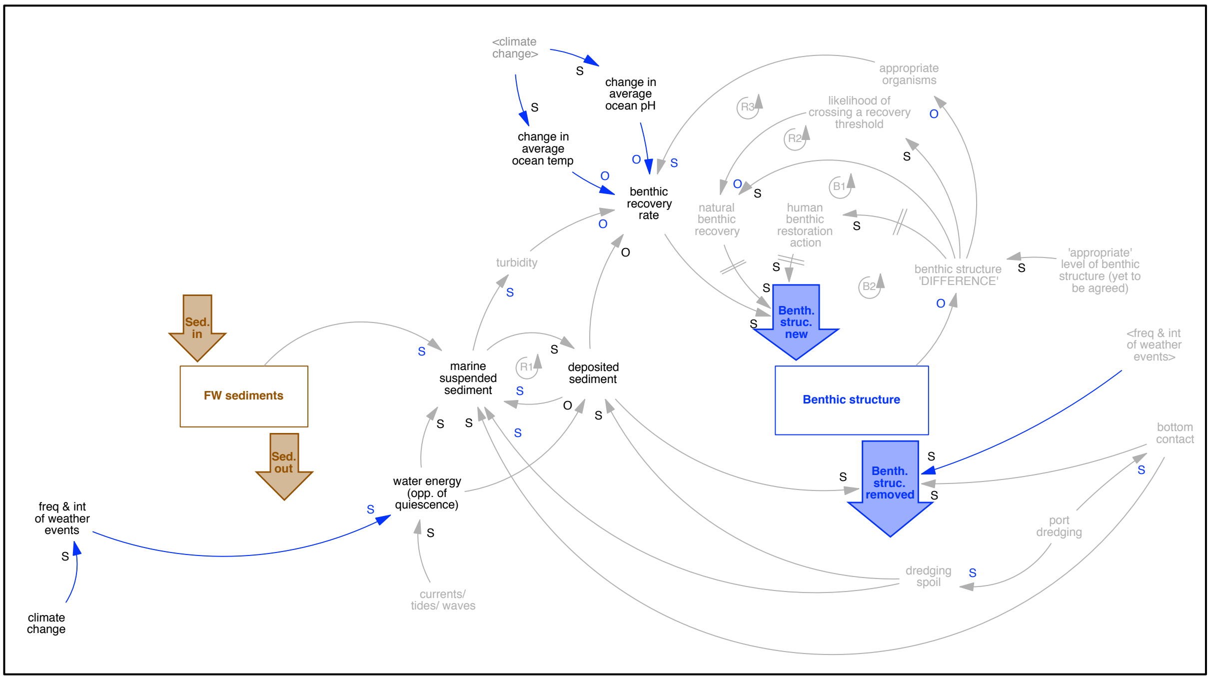
Firstly, it can increase the *change in average ocean temperature* and the *change in average ocean pH*. These are the remaining two factors identified that influence the *benthic recovery rate*, both of which are expected to reduce the *benthic recovery rate* for benthic structures currently expected in Hawke's Bay.[3]

Secondly, any increase in the *frequency & intensity of weather events* is likely to lead to more benthic structure being removed from Hawke's Bay. For example, this could occur through gravel beds being moved, kelp forests stripped, or reefs broken up.

A greater *frequency & intensity of weather events*, in conjunction with natural *currents, tides and waves*, will also increase the amount of *water energy*. This will stir up more deposited sediment and maintain more suspended sediment.

[3] It is noted that for some types of fauna benthic structure that are not endemic to the area or are invasive, climate change may actually make conditions more suitable for them. The relationships articulated here relate to the impact climate change would have on those types of benthic structure traditionally established or expected in Hawke Bay.

Figure 20. The impact of climate and climate change

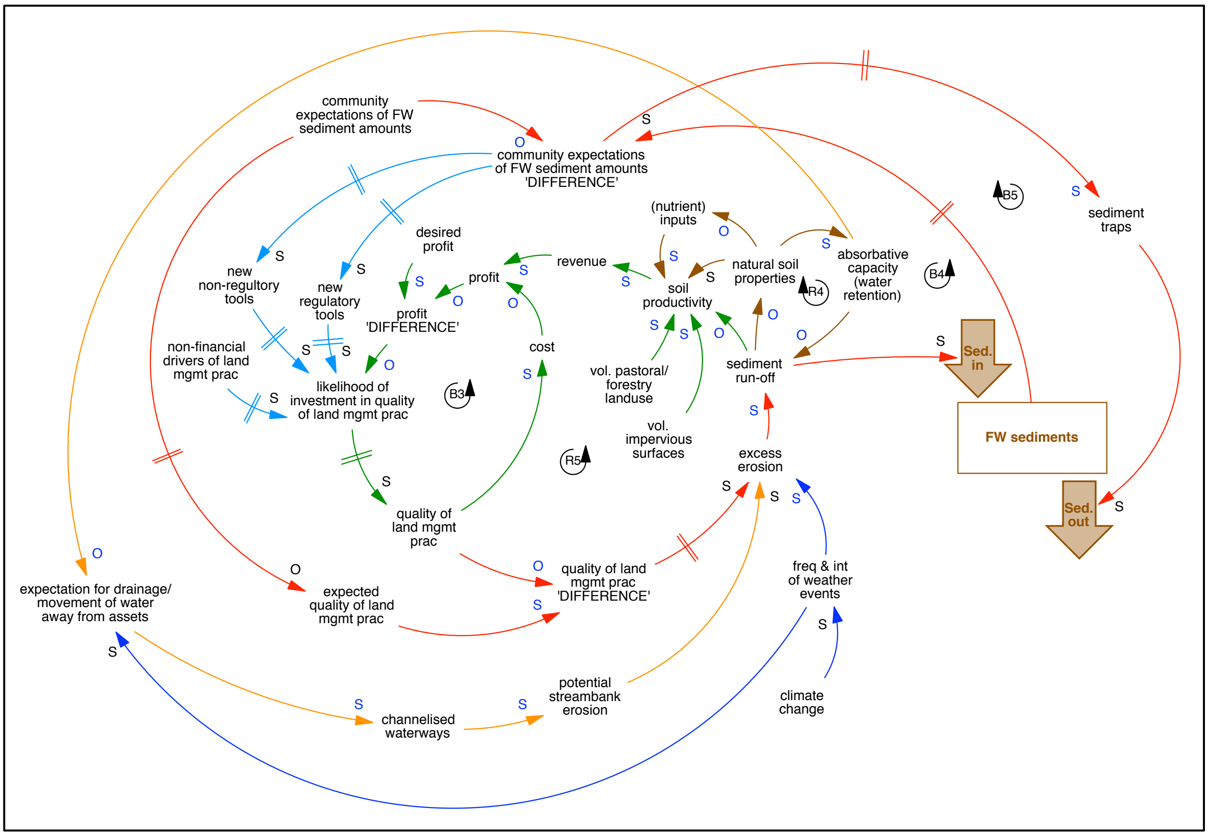


6.2. Loops influencing freshwater sediments

This section describes the loops identified that influence the freshwater sediment load.

As noted earlier (section 6.1.2), freshwater sediments are defined as the level of freshwater sediments that flow into Hawke's Bay. A summary of the section of the system map discussed here is shown in Figure 21.

Figure 21. Overview of the influences on freshwater sediments



6.2.1. Revenue and cost loops of soil management

The vast majority of land in the Hawke's Bay region is used for productive purposes. Therefore, the profit loops of landuse are central to this part of the system map (Figure 22).

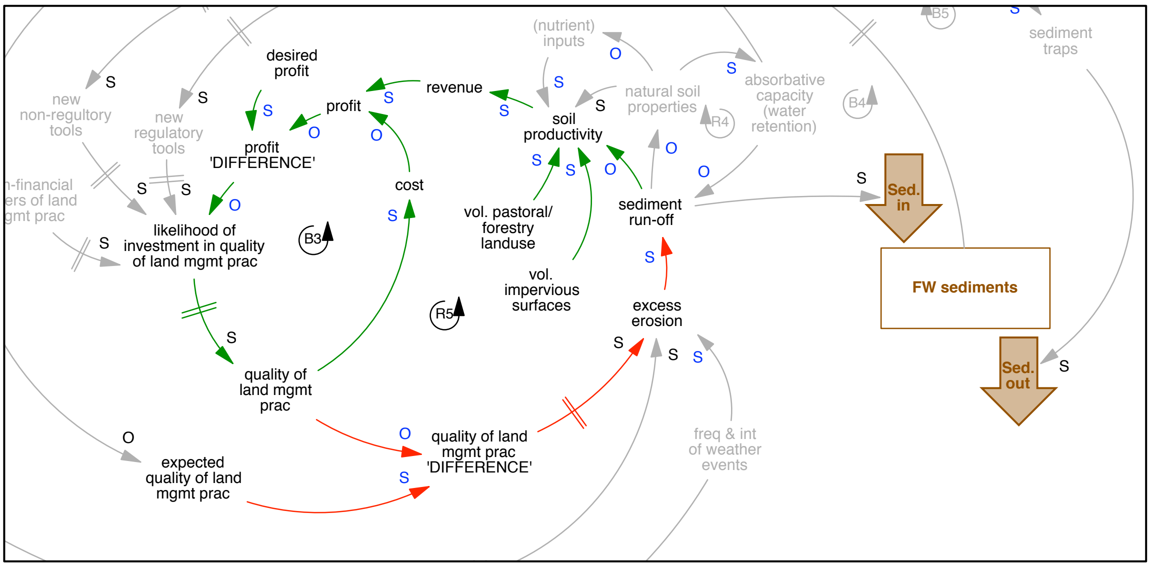
Two goal/gap structures play an important role in these loops: firstly, a goal/gap relationship between the *expected* and *actual* quality of land management practices; and secondly, a goal/gap relationship between *desired* and *actual* profit.

The profit loop (**R5**) shows that the *quality of land management practices* influences the amount of *excess erosion* which in turn influences the *sediment run-off*. As erosion is a natural process, the term *excess erosion* has been used. This is a factor where, when this system map is used in a certain geographic location, what is deemed 'excess' in relation to natural erosion can be considered in the discussion.

If *excess erosion* is kept low then the amount of *sediment run-off* is also kept low, the more sediment is retained, then the greater the *soil productivity*. Soil productivity here is also influenced in a quantitative fashion by the amount of land in productive use and in impervious surfaces (e.g. urban areas, roads, etc). The greater the *soil productivity* then greater the *profit* from that productive soil.

At this point we come to the second goal/gap of *profit*. The greater the *profit,* the lower the *profit 'DIFFERENCE'*, therefore the greater the *likelihood of investment in quality land management* *practices*. Over time (after a delay) this will lead to an increase in the quality of actual land management practices, due to investment in staff, capital or process. In turn this continues to bring land management practices closer to expectations, which reduces *excess erosion*, and so on the loop continues to reinforce.

Figure 22. Revenue and cost loops of soil management



The cost loop (**B3**) shows that theoretically, as the *actual quality of land management practices improve*, this generally will increase costs, which in turn reduces profit. In turn this has the opposite effect on the part of the loop that is shared with the profit loop – less *profit* leads to a greater *profit 'DIFFERENCE'*, which reduces the *likelihood of investment in quality of land management practice*, which over time will reduce the actual *quality of land management practice*.

As these two loops are strongly linked, their impact on each other will compete and the eventual *quality of land management practices*, *excess erosion* and *sediment run-off* will be influenced by the loop that dominates the strongest.

6.2.2. Natural soil properties

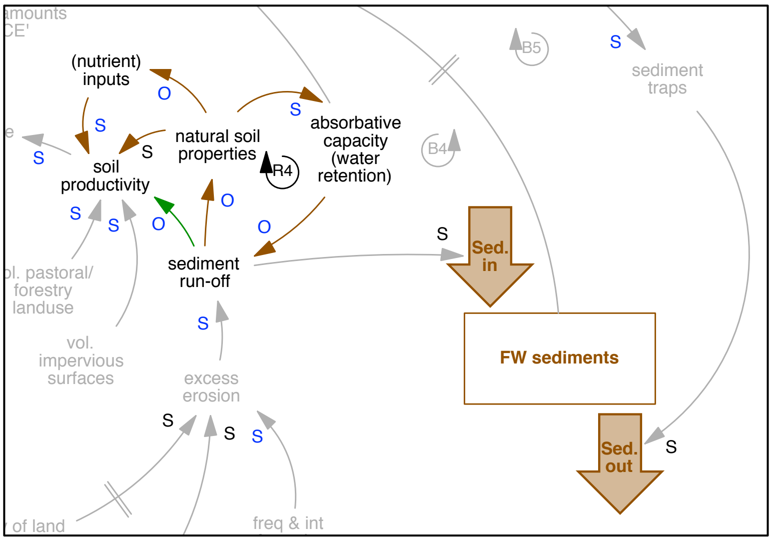
Natural soil properties are another important subset of influences that plan an important part in the amount of sediments that reach freshwater bodies (Figure 23).

In addition to the quantitative contributions to soil health mentioned in the previous section, these properties account for the qualitative contributions. These are the *natural soil properties* – the extent to which soil retain their natural healthy biota and nutrients, the level of *(nutrient) inputs* – those inputs that are added to increase productivity of soils, and the *absorptive capacity (water retention)* of the soil – the ability of soil to naturally retain water, therefore maintaining its moisture content, delaying water run-off and thus reducing overly dry and erosion prone soils.

A reinforcing loop (**R4**) exists where the greater the *natural soil properties*, thus the greater the *absorptive capacity (water retention)* of the soil, and *sediment run-off* is reduced; as a result, more soil is retained which in turn continues to retain the *natural soil properties*. Thus reinforcing the original condition.

Maintaining high *natural soil properties* also leads to increased *soil productivity*. At the same time, it will also lead to less *nutrient inputs* being used, which will decrease *soil productivity*. These two pathways will compete. The *inputs* pathway will compensate for a lack (or loss) of *natural soil properties*. The pathway that dominates will depend on the level and health of *natural soil properties*.

Figure 23. **Natural soil properties**



6.2.3. Community expectations of sediment in freshwater

The *community expectations of freshwater sediment amounts* is an important driver of several pathways of influence, being involved as a key driver in two loops (Figure 24).

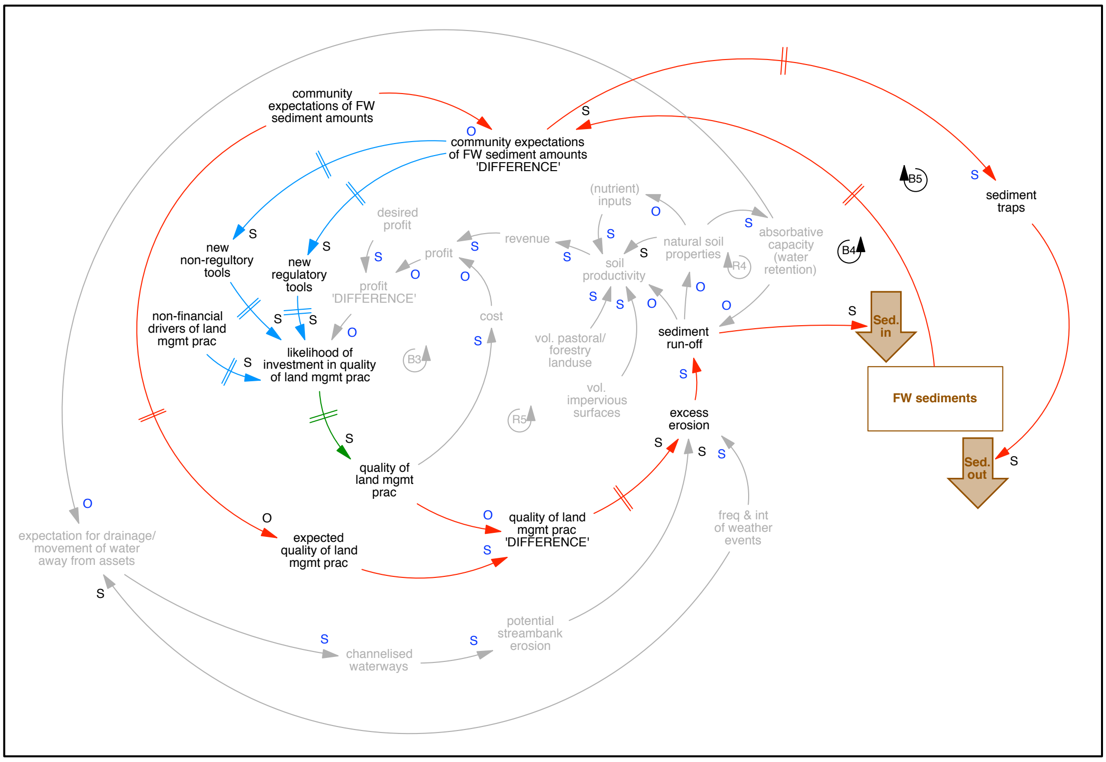
Here, the *community expectations of freshwater sediment amounts* forms the *goal* part of a goal/gap relationship with the stock of *actual freshwater sediment amounts*. This goal/gap works slightly differently to the other, because the goal is the *lower* of the two (a bit like a low score is the desire in a game of golf). When the actual sediments are in excess of (i.e. higher than) these expectations, then these expectations are not being met. The rest of the goal/gap structure works the same way, where the larger the gap (the further away from the goal), then the more pressure this gap exerts on other factors.

If the gap is large, then over time this increases pressure to **stop sediment entering waterways** by developing *new regulatory* and *non-regulatory tools*. As these are developed, there is a lag before these are implemented and become effective, thus increasing the *likelihood of investment in quality of land management practices* (which is also influenced by the *non-financial drivers of land management practices* – or landowners desire to do good). This will eventually increase the actual quality of practices, reduce *excess erosion*, and reduce *sediment run-off*, meaning less *sediments in* freshwater bodies, which means a lower *freshwater sediment* load. Eventually this will bring the actual levels in line with the expected levels (loop **B4**), but there are several long delays in this loop.

At the same time, a smaller direct loop to **remove sediment from waterways** (**B5**) is also operating. Here an increased community expectations gap will eventually lead to more *sediment traps* in waterways, which will help take *sediment out* of the freshwater bodies, which reduces the stock of suspended *sediment in freshwater bodies*, eventually bringing actual amounts in line with community expectations.

At the same time, the *community expectations of freshwater sediment amounts* also drives (with a delay) the *expected quality of land management practice*. This in turn plays an important part in the goal/gap structure relating to whether the *quality of land management practices* is in line with expectations.

Figure 24. Community expectations of sediment in freshwater



6.2.4. Community expectations of drainage infrastructure

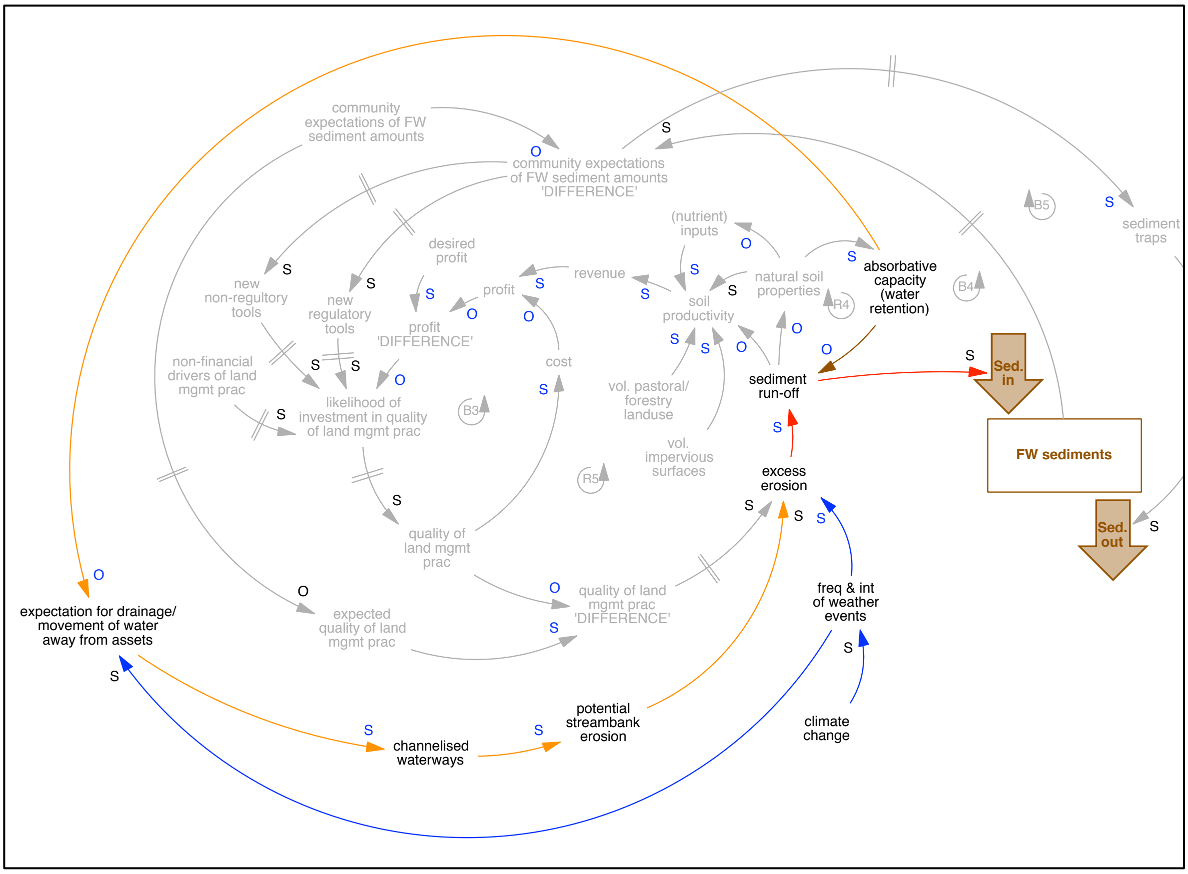
Finally, the *expectation for drainage/movement of water away from assets* is the other important community expectation that has influence on *sediment run-off*.

An increased desire for rapid movement of water away from constructed assets has traditionally led to an increase in *channelised waterways*, which has increased *potential streambank erosion*, encouraged *excess erosion* and *sediment run-off*, leading to more sediments in freshwater (Figure 25).

At the same time, increased *frequency and intensity of weather events* will also lead to increased *excess erosion*, and an increase in *expectation for drainage/movement of water away from assets*.

Importantly, the system map highlights the important role that increasing the *absorptive capacity (water retention)* of soils will have in alleviating these pressures. Firstly, this will help retain soils and reduce *sediment run-off*. Secondly, it will slow the rate at which water moves off the land, likely reducing high flows during weather events, thus reducing the *expectation for drainage/movement of water away from assets*.

Figure 25. Community expectations of drainage infrastructure



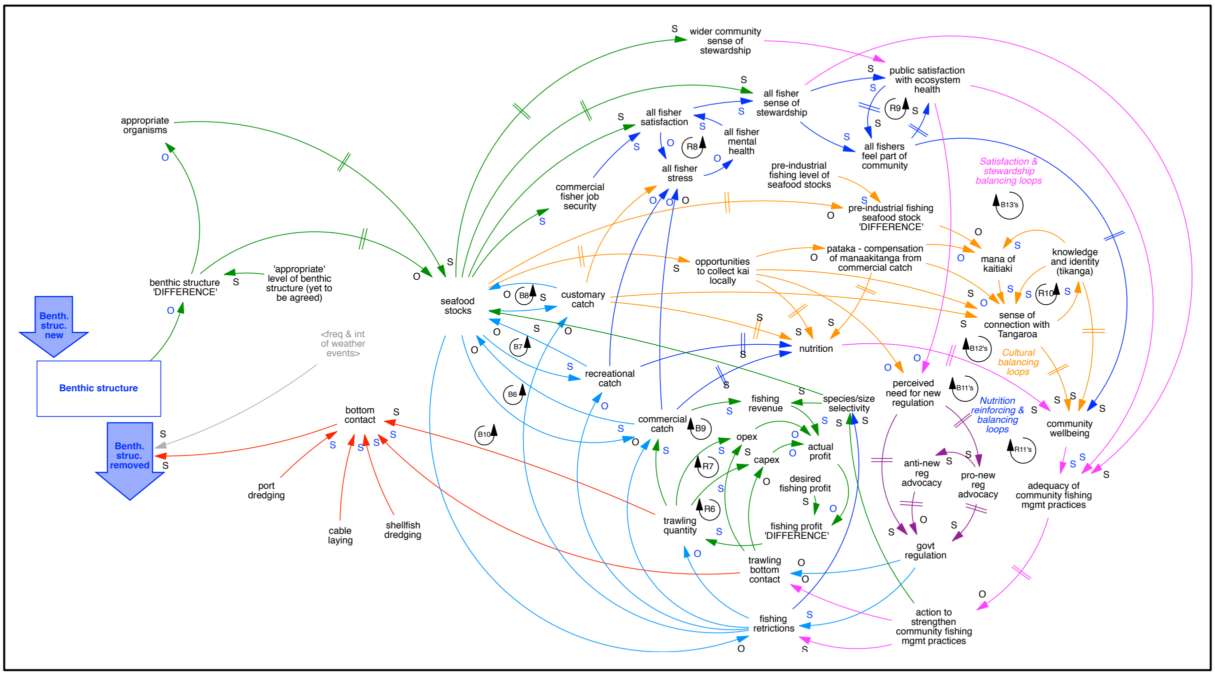
6.3. Socio-economic loops linked with benthic structure

This section describes the third part of our system map, those socio-economic loops that have been identified as influencing, or being influenced by, benthic structure (Figure 26).

Two factors are critical links between these parts of the map – *seafood stocks* and *bottom contact*.

A large number of factors and loops were identified in this part of the map, which is to be expected as this reflected the speciality and experience of the majority of the stakeholders involved in the process. Indeed, it reflects strongly the dynamic reasons why the HBMaC Group was formed – *to achieve a healthy and functioning marine ecosystem that supports a sustainable fishery*.

Figure 26. Overview of the socio-economic loops linked with benthic structure



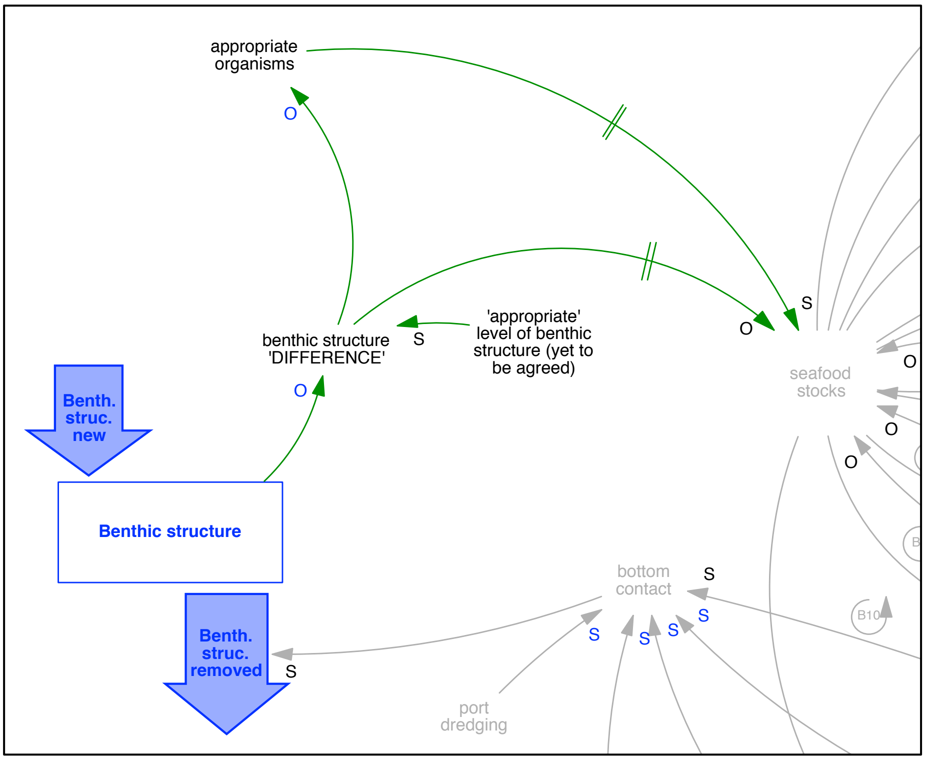
6.3.1. Benthic structure and seafood stocks

The role of the *benthic structure DIFFERENCE* in the loops that generate benthic structure has been discussed in section 6.1.4. However, this factor is one of two key influences of the factor *seafood stocks*. The other is *appropriate organisms*. These influences reflect the role that the benthic structure and the organisms that it supports play in supporting abundant *seafood stocks* (Figure 27).

Delays are marked on both of these influences to represent the time lag that it takes for these influences to recover (not so much once they are in balance).

The lower the benthic structure DIFFERENCE, the more in balance the benthic structure is. Therefore, it is more likely to support` *appropriate organisms* and *seafood stocks*.

Figure 27. Benthic structure and seafood stocks



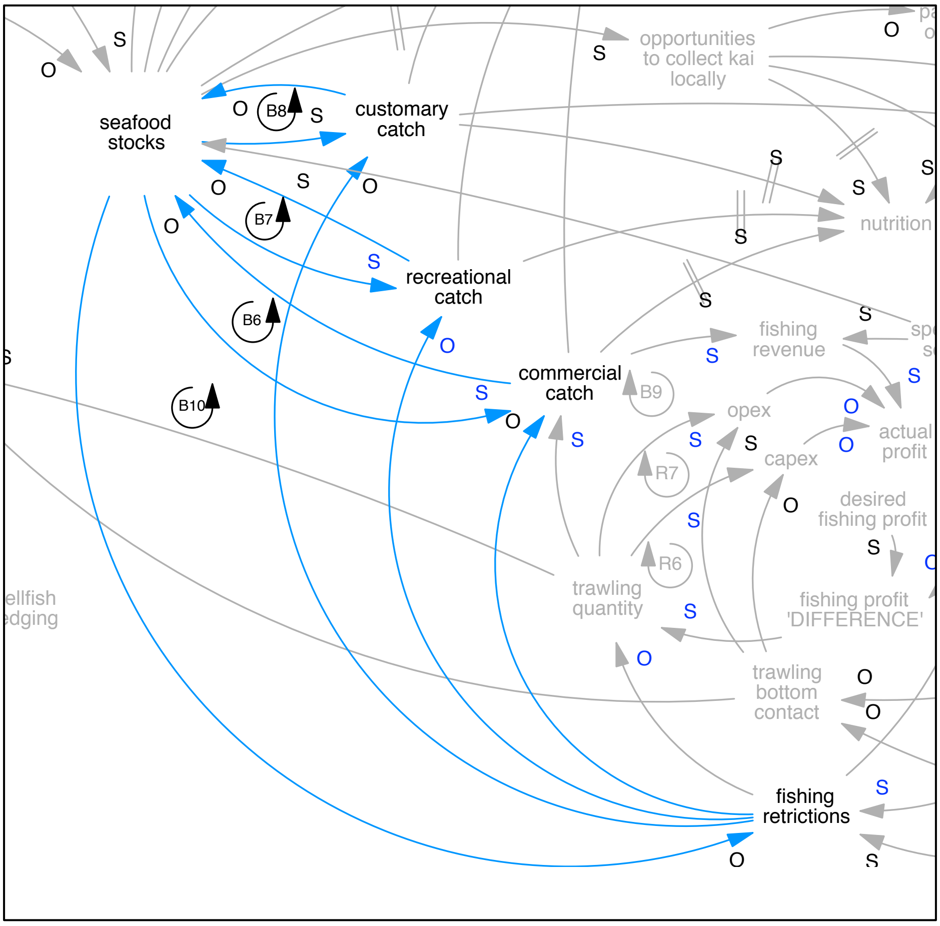
6.3.2. Quota Management System loops

The series of light blue loops shown below describe influences that can be summarised as the core of the Quota Management System (QMS) (Figure 28).

Here, the three types of catch defined within the QMS are shown: *customary catch*; *recreational catch*; and *commercial catch*. Each of these are in their own balancing loop with *seafood stocks* (**B6**, **B7**, & **B8**) – the more catch that is taken then the less seafood stocks there are, over time this results in less catch.

As *seafood stocks* fluctuate, this will have an opposite effect on the amount of *fishing restrictions* that are put in place via the QMS. For example, if *stocks* are high, then *restrictions* may be reviewed down; conversely, if stocks are low then restrictions are likely to increase. This is represented by balancing loop **B10**. Changes in *fishing restrictions* then go on to affect the different types of *catch*. Although there are in fact three pathways that this loop operates by, it has been labelled as one because this is one of the primary ways that the QMS operates.

Figure 28. Quota Management System loops



6.3.3. Quota Management System loops – potential alternative representation

This section demonstrates a potential alternative representation of the Quota Management System loops, to that described in the previous section (6.3.2).

It was noted in the *Background* section (see section 2.4), that some Māori participants had some discomfort around the ability of the system mapping approach to adequately represent Te Aō Māori perspectives. The representation of specific terms used in the Quota Management System legislation is one of these areas of discomfort.

Here, the terms *commercial*, *recreational* and *customary catch* have very specific meanings under the relevant legislation. While they are active legislative words with specific meanings, Māori participants have highlighted that such terms are not consistent with a Te Aō Māori perspective. Rather, they view all catch as catch, regardless of its eventual use. One single catch of fish could in fact be serving multiple purposes within Te Aō Māori, such as fulfilling both a recreational and cultural need for an individual fisher. Indeed, these needs may not even be adequately described or articulated by the terms defined in the legislation.

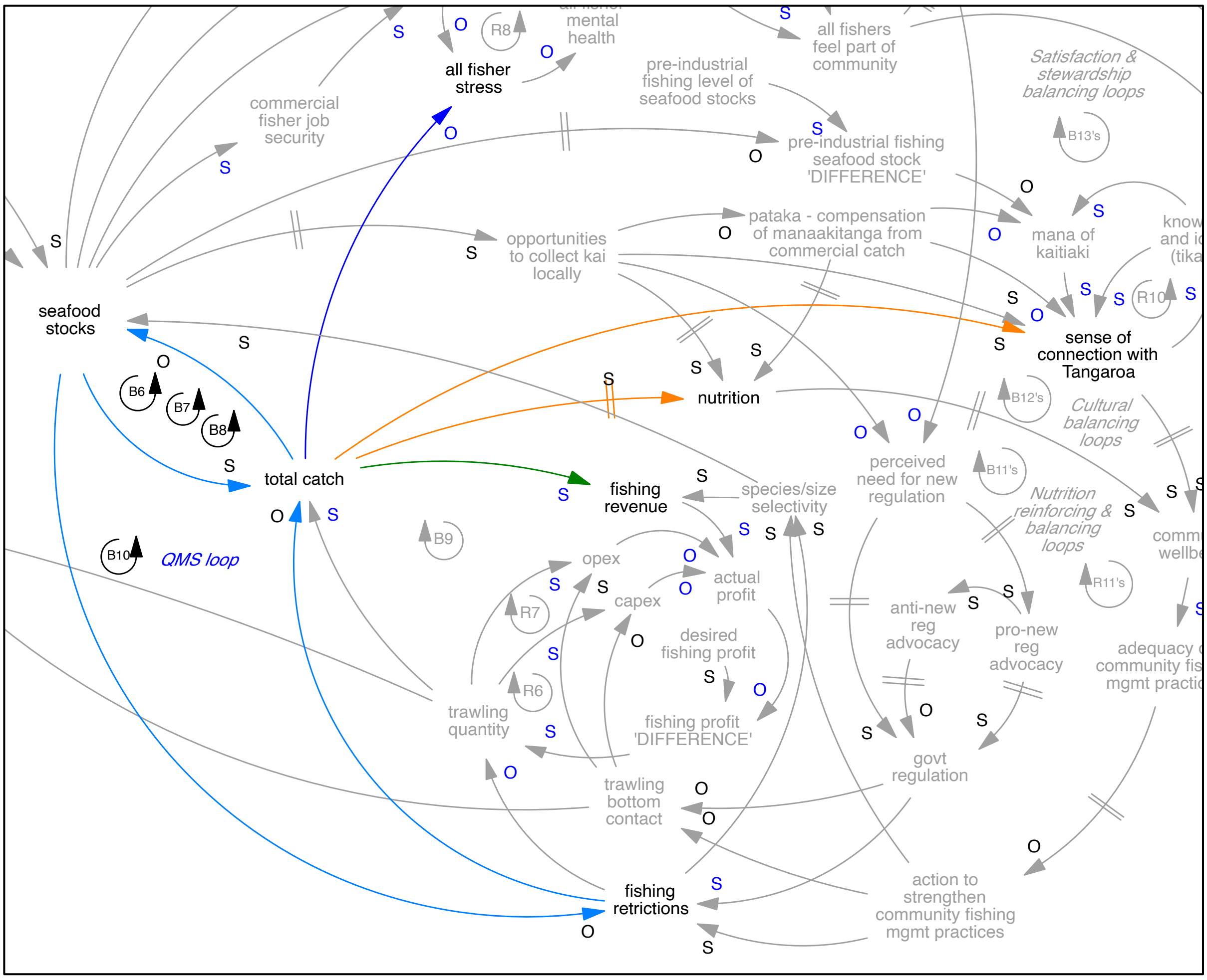
Consequently, an alternative articulation of this part of the system map is offered here (Figure 29).

Here, one single node has been used to represent *total catch*, instead of *commercial*, *recreational* and *customary*. Along with *seafood stocks* and *fishing restrictions*, *total catch* forms a balancing loop representing the mechanisms of the QMS (**B10**). Within this loop operate the various forms of quota management and definitions that currently exist, as well as allowing this to also succinctly represent any potential future iteration of such a legislation.

In addition, the influences from the previously three types of catch have all been retained to other relevant parts of the map: *all fisher stress*; *fishing revenue*; *nutrition*; and *sense of connection with Tangaroa.* Depending the type of catch being considered, these influences will operate at varying strengths or remain dormant.

The three balancing loops previously representing the dynamic influence between catch and seafood stocks (**B6**, **B7** & **B8**) have all been retained to ensure consistency of numbering with the rest of the map. However, these are no longer three separate loops, it is just one.

Figure 29. Quota Management System loops – possible alternative representation

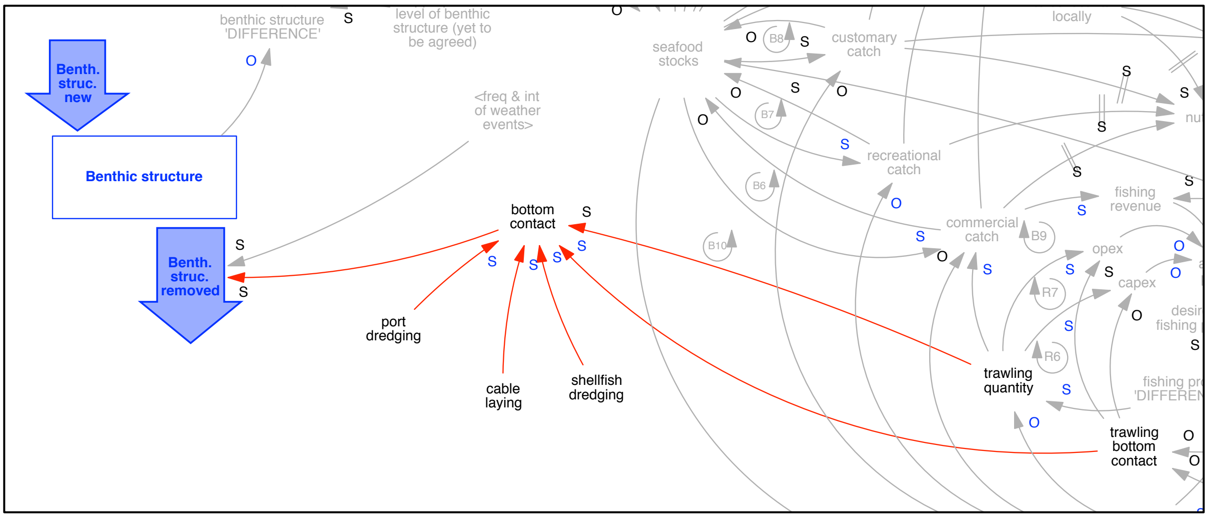


6.3.4. Factors that impact bottom contact

The factor of *bottom contact* as a catch-all for the contact of human activity on the seabed has already been discussed in section 6.1.5. Here, the various ways in which *bottom contact* occurs are outlined (Figure 30).

Five factors are described. *Port dredging* has already been discussed in section 6.1.5 and is a regular activity in Hawke's Bay. *Cable laying* has been included, although it is understood there is not much of this in Hawke's Bay. *Shellfish dredging* describes commercial activities for harvesting shellfish, as recreational efforts are not believed to be significant. While this is also a lesser activity traditionally, there are some proposals for more commercial *shellfish dredging* in the future. Trawling activity is the predominant *bottom contact* activity in Hawke's Bay and two factors have been used to describe it here: firstly, *trawling quantity*, which describes the *amount* of trawling activity occurring; and secondly, *trawling bottom contact*, which describes the average amount of bottom contact that trawling activity makes (e.g. this is reduced or made less impactful by using certain type of gear). In effect these two factors describe the *quantity* and *quality* of trawling activity.

Figure 30. **Factors that impact bottom contact**



6.3.5. Revenue and cost loops of commercial fishing

This section outlines the revenue and cost loops of commercial fishing. Here, the revenue loop is a balancing loop where the *desired fishing profit* and the *actual profit* influence the *fishing profit DIFFERENCE*. The greater this difference the more trawling activity (*trawling quantity* as a measure of the volume of trawling carried out) is encouraged, leading to greater *commercial catch*, greater *fishing revenues* and greater *actual profit* (all other things being equal). The key driver of this loop is the *desired fishing profit*. So long as that remains the same and there are plentiful fish to catch, the revenue loop will find balance.

However, this loop is also influenced to two reinforcing loops relating to capital expenditure (*capex*) and operating expenditure (*opex*). Here, greater *trawling quantity* increases both *capex* and *opex*, which both reduce *actual profit*, increasing the *fishing profit DIFFERENCE* and thus encouraging more *trawling activity* to try to make up the shortfall. The actual *trawling quantity* will be the result of the combination of these loops and whichever one dominates.

The other important factor here is *trawling bottom contact*. This was articulated by stakeholders as a measure to describe the *quality* of trawling activity and the amount that it touches the sea floor.

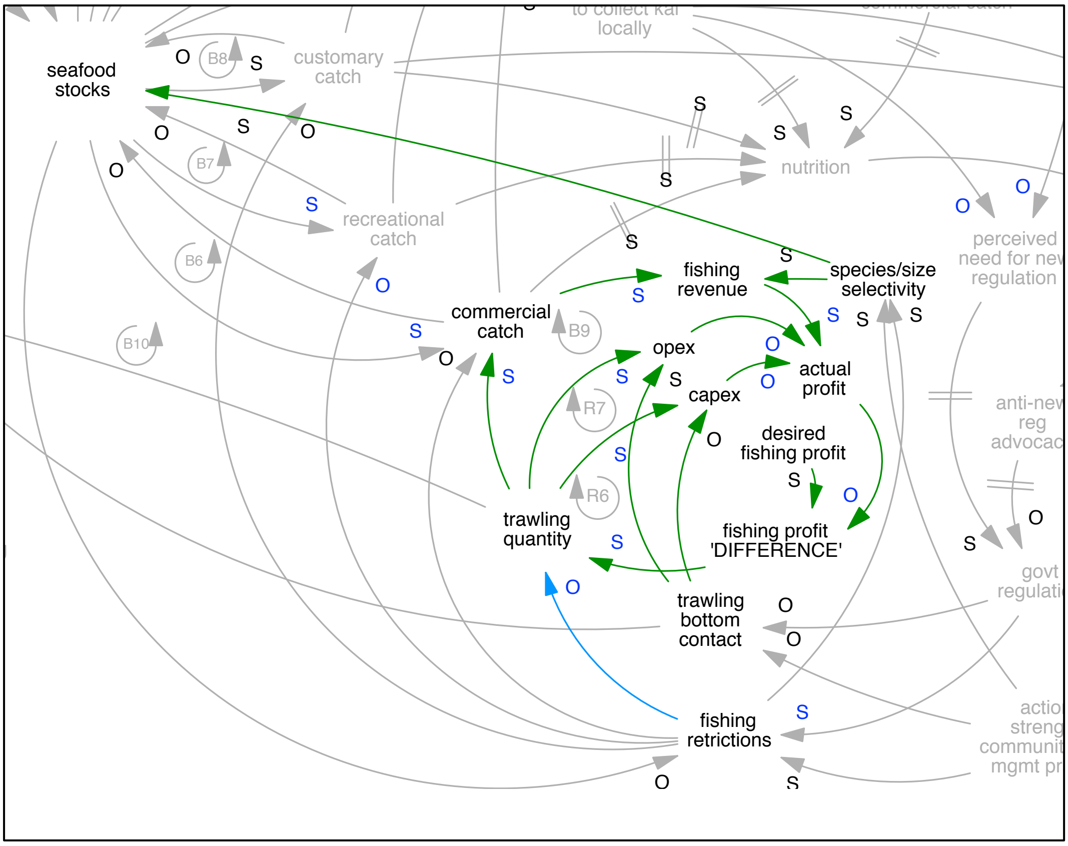
By definition, trawling will involve contact with the ocean floor, yet this can be minimised by investing (*capex*) in gear that minimises the bottom contact – therefore reduced *trawling bottom contact* will lead to an increased *capex* spend.

At the same time however, this will also result in efficiencies in fuel use, due to the reduced drag on the bottom – therefore reduced *trawling bottom contact* will also lead to reduced operational expenditure (*opex)*.

The other factor highlighted here is *species/size selectivity*. This factor represents a deliberate strategy on behalf of the fisher to target certain species or minimum sizes. The intention of this is to improve the provenance of the fish (by enhancing the reputation of the fisher and their practice) and perhaps even catch-to-order. Both are strategies that would lead to a higher premium price for any catch, this the link to *fishing revenue*.

If *species/size selectivity* is increased, then the overall catch would reduce, thus potentially improving *seafood stocks* (assuming the same amount of effort).

Figure 31. **Revenue and cost loops of commercial fishing**



6.3.6. How change manifests – regulation or community management

This section of the map describes the two main pathways via which action can manifest (Figure 32). These are effectively legislative and voluntary, being described as *government regulation* and *community fishing management practices*. The second of these is represented by two factors – *adequacy of community fishing management practices* which has an opposite relationship with *action to strengthen community fishing management practices*. That is, the better the *adequacy* the less need for *action*; or the lower the *adequacy* the greater the need for *action*. The delay in this link represents the time that this influence takes to manifest.

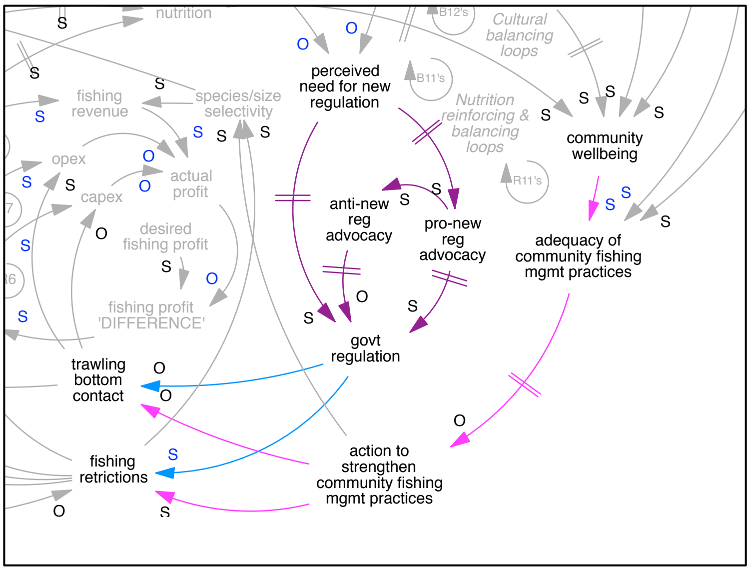
Both *govt regulation* and *action to strengthen community fishing management practices* have similar influences on the two key factors that influence the rest of the loops in this part of the map – *trawling bottom contact* and *fishing restrictions*.

If there is more *govt regulation* or *community action*, then both of these are likely to lead to greater *fishing restrictions* or less *trawling bottom contact*. They are just achieving this through regulated or voluntary action.

Community wellbeing is a core driver of the *adequacy of community fishing management practices*. The pathway that both these factors creates forms the lower part of several loops, which are described in the following sections.

Govt regulation is also the lower pathway for a couple of loops which are described following. This occurs if the *perceived need for new regulation* increases. If this occurs, one pathway may be that this eventually results in an increase in *govt regulation*. Another pathway is that the perceived need generates greater *pro-new regulation advocacy*. While this itself may eventually lead (delay) to greater *govt regulation*, it is also assumed that this activity also generates more *anti-new regulation advocacy* in response, which may lead (delay) to no increase in *govt regulation*.

Figure 32. How change manifests – regulation or community management



6.3.7. The drivers of change – nutrition

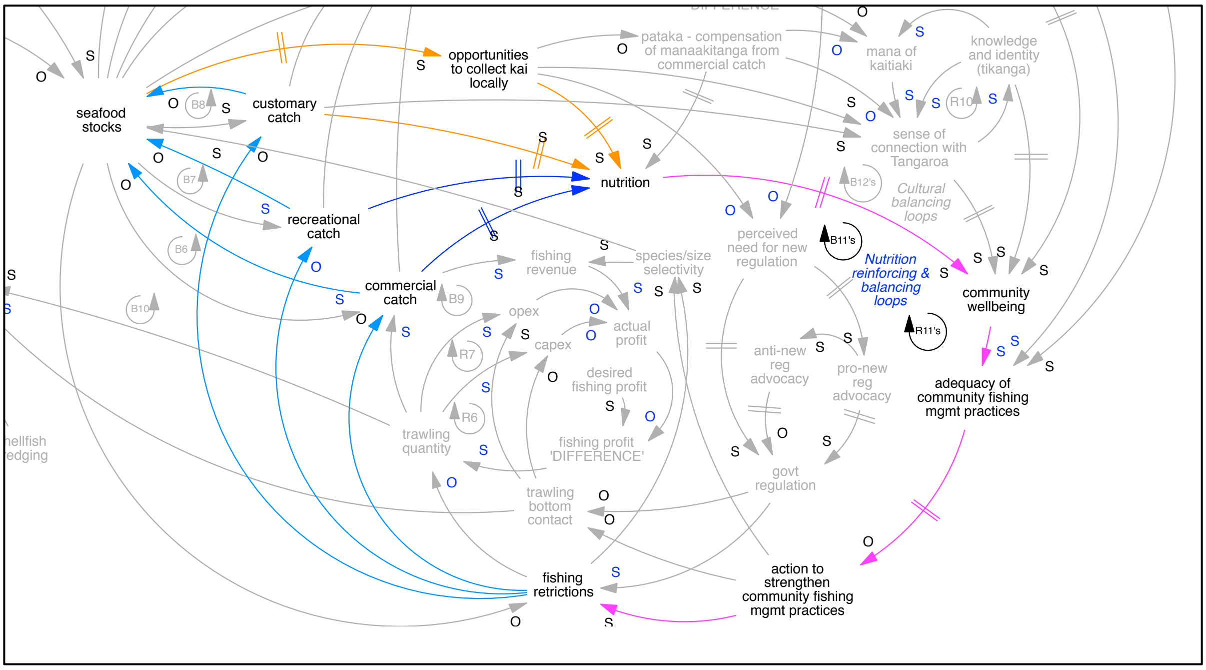
Nutrition was identified by participants as a factor to be included and it is influenced by two sets of loops – one reinforcing, one balancing (Figure 33).

Originally added to the map in relation to Māori nutrition, this factor was seen to be influenced by the *opportunities to collect kai locally* (being the abundance of kai in the near shore area) and the level of any *customary catch* taken. Group discussion highlighted that *recreational* and *commercial catch* also supported nutrition but via slightly different pathways. For *recreational* this tended to be line fishing, while for *commercial* this tended to be through the purchase of seafood.

High levels of *nutrition* on its own leads to high *community wellbeing* and *adequacy of community fishing management practices*, which in turn reduces the need or *action to strengthen* those practices. This would result in no new *fishing restrictions* which in turn encourages the three kinds of ongoing catch (*customary*, *recreational* and *commercial*), which over time results in ongoing high levels of *nutrition*. This is a reinforcing loop (**R11**) that operates via the three pathways of catch type.

At the same time, as each *catch* type is by definition taking seafood, this leads to (at least temporarily) a reduction in *seafood stocks*. This will (at least temporarily) reduce the *opportunities to collect kai locally*. If this pathway is substituted into the loop already described (in place of the *catch – nutrition* link), then it becomes a balancing loop (**B11**). Here additional catch reduces *seafood stocks*, which reduces the *opportunities to collect kai locally*, which reduces *nutrition*. The impacts of this loop manifest themselves particularly strongly in a reduction in *opportunities to collect kai locally*.

Figure 33. **The drivers of change – nutrition**



6.3.8. The drivers of change – the many influences on cultural satisfaction

A large section of this part of the map is made up of factors relating to cultural satisfaction (Figure 34). These are described in more detail here.

While *opportunities to collect kai locally* and how that influences *nutrition* have been described in the previous section, it is also highlighted in this section, as community nutrition and health is a very strong part of cultural satisfaction.

In addition, having *opportunities to collect kai locally* is also a very important part of maintaining a strong *sense of connection with Tangaroa*, through an active connection with the ocean as part of food collection and the provision of manākitanga. The greater the *sense of connection with Tangaroa* then the greater the *community wellbeing*.

The *sense of connection with Tangaroa* is one of the main factors in this area. It forms its own reinforcing loop (**R10**) with *knowledge and identity (tikanga)*, where increased *connection with Tangaroa* leads to more opportunities to interact with whanau, share *knowledge* and *tikanga*, thus strengthening *identity*, which in turn further strengthens the connection with *Tangaroa*. At the same time, increasing *knowledge and identity (tikanga)* also increases the *mana of kaitiaki*, which also further increases the *connection with Tangaroa*.

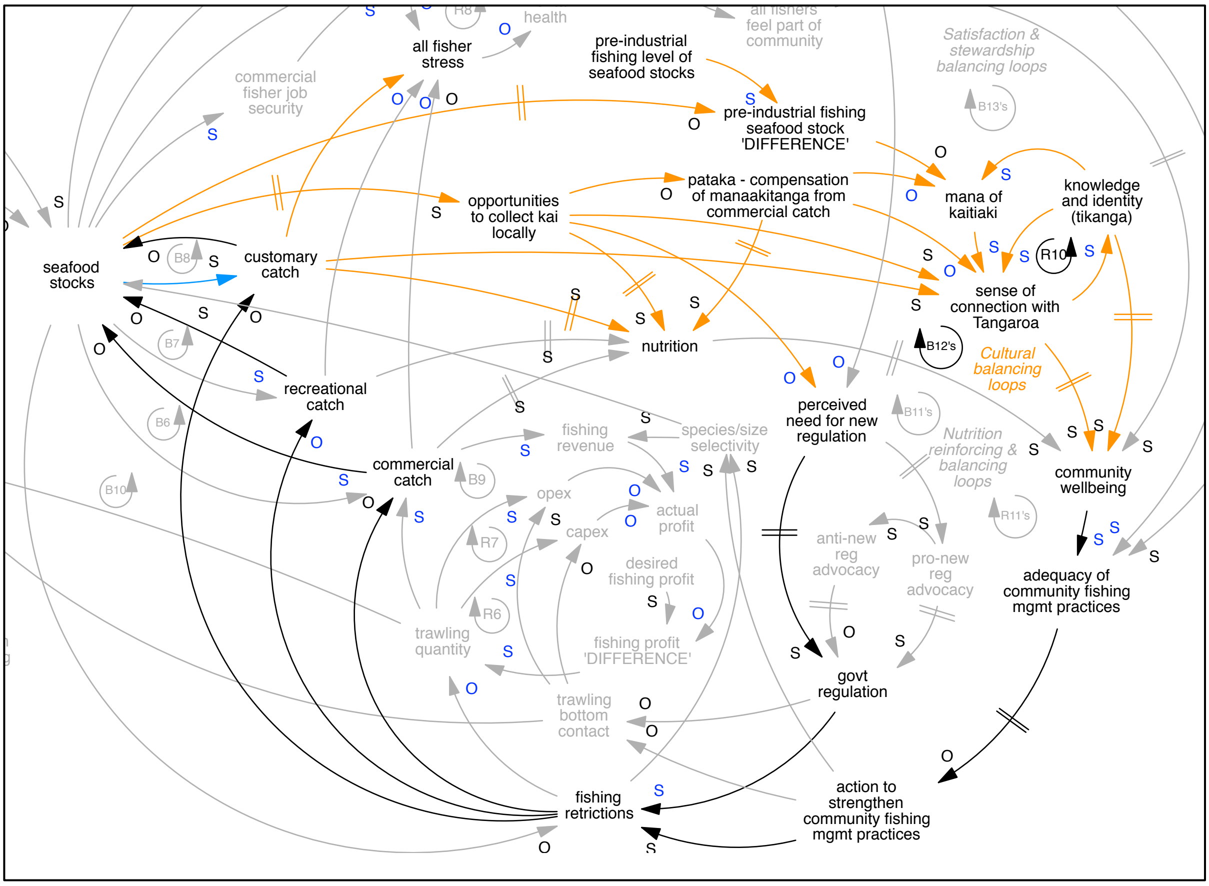
The *mana of kaitiaki* was also a node that was identified as being of major importance. Here, the dynamics of kaitiaki being able to leave their rohe in as good or better condition than when they were born was identified as being a key driver of satisfaction. In terms of the seafood stocks, the yardstick for this was noted as being the *pre-industrial fishing level of seafood stocks*. That is, kaitiaki have sought (and do seek) seafood stocks to reach the level that they were before the era of industrial fishing (note – not pre-European contact). Therefore, the stronger this ability, then the better potential for stewardship of marine resources.

This factor forms the 'goal' in this goal/gap structure and part of a very important wider balancing loop (one of the **B12s**). Here, the greater the difference between the *pre-industrial seafood stocks* and the actual *seafood stocks*, will mean less *mana of kaitiaki* and a lower sense of connection with *Tangaroa*. The balance of this loop would see this influence flow through the other influences of *community wellbeing*; *community fishing practices*; *fishing restrictions*; *catch*; and back into *seafood stocks*. This part of the **B12** loops is important to note because it effectively is saying that the *mana of kaitiaki* will always be lower than desired, so long as the actual levels of *seafood stocks* remain lower than they were prior to *pre-industrial fishing*.

The other factors already described – *customary catch* and *opportunities to collect kai locally* – form the other pathways of balancing loops **B12**.

The only factor remaining to describe here is *pataka – compensation of manākitanga from commercial catch*. When *opportunities to collect kai locally* are low, this describes the situation that occurs where provision can be made to feed whanau from the commercial catch quota owned by Iwi. While this enables the provision of *nutrition*, it does not provide for the *connection with Tangaroa* that occurs as part of collecting kai, nor does it enhance the *mana of kaitiaki*.

Figure 34. The drivers of change – the many influences on cultural satisfaction



6.3.9. The drivers of change – the many influences on community satisfaction

This final section describes the loops associated with broader community satisfaction and stewardship. Factors in this area (see Figure 35) are described at different levels; some apply to the wider public or community, others apply to fishers (all kinds) specifically, while one applies only to commercial fishers.

Beginning with the more specific first, increased *seafood stocks* will increase *commercial fisher job security*. In turn, this, and the levels of *seafood stocks* in general, both increase *all fisher satisfaction*, which in turn increases the *all fisher sense of stewardship* (or the sense that they are being good stewards of the ocean). In addition to this pathway, *all fisher satisfaction* is part of a reinforcing loop (**R8**) with two other factors – *all fisher stress* and *all fisher mental health*. This describes how if *satisfaction* is high (due to plentiful seafood and job security), then *stress* is reduced and *mental health* is increased, which further reinforces *satisfaction*. While *seafood stocks* are plentiful this spirals in a positive way; when they are not plentiful, it spirals in a negative way.

As well as a specific *fisher sense of stewardship*, healthy seafood stocks also result in a general *wider community sense of stewardship*.

The greater the *all fisher sense of stewardship* then the more that *all fishers feel part of the community* and the more *community wellbeing* is increased.

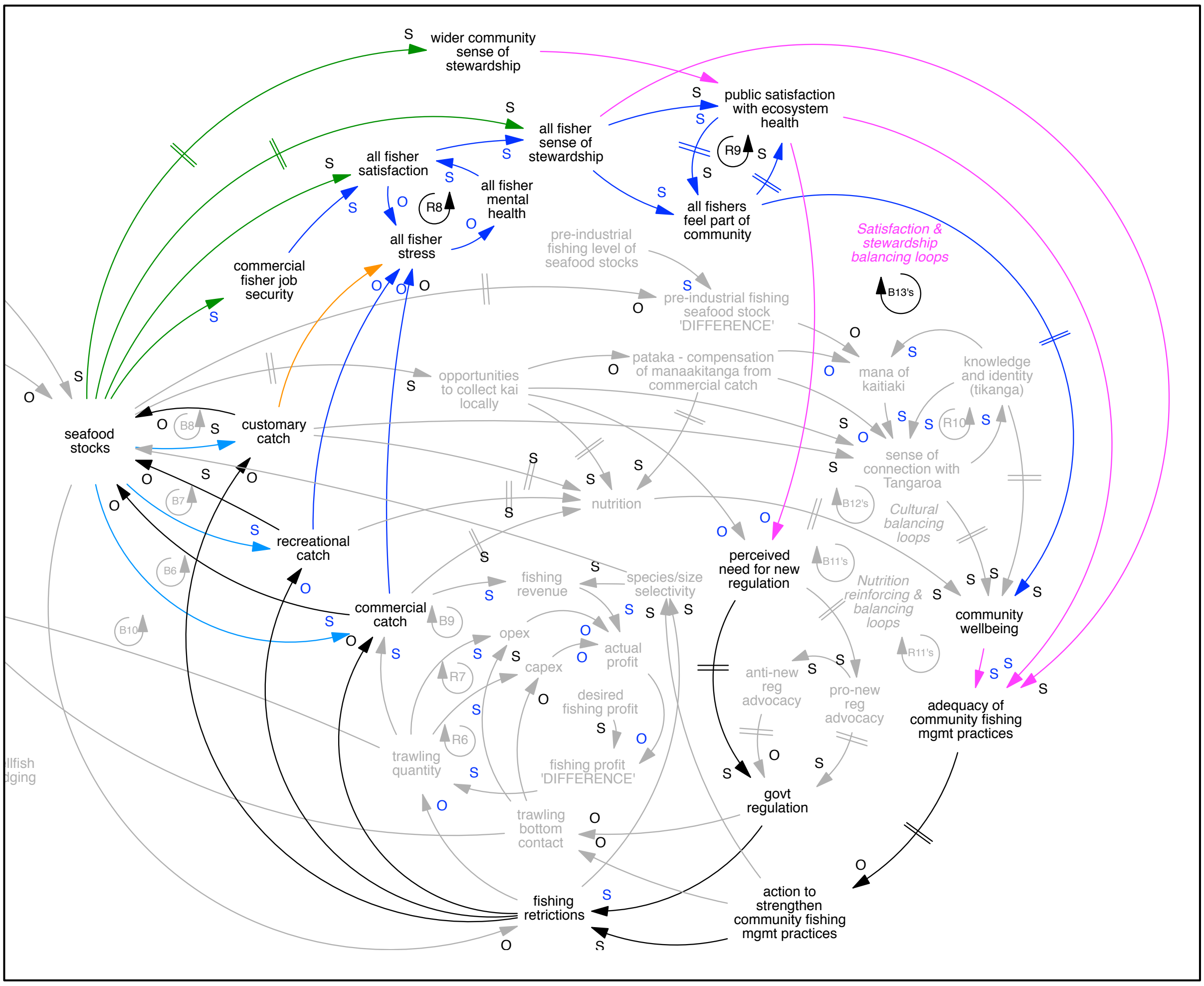
The fisher sense of being *part of the community* is also part of another reinforcing loop (**R9**). Here, the more that *all fishers feel part of the community*, the greater the *public satisfaction with ecosystem health*. Ecosystem health here has been used as a generic term for the general wellbeing of the environment, of which healthy seafood stocks can be viewed as a contributing indicator. Again, if *seafood stocks* and *fisher satisfaction* are high then this operates in a positive way, otherwise it can revert to a negative spiral.

Public satisfaction with ecosystem health is also influenced by the *wider community sense of stewardship*.

Finally, a strong level of both *all fisher sense of stewardship* and *public satisfaction with ecosystem health* will mean that there is *adequacy of community fishing management practices*. Public satisfaction with ecosystem health will also result in less *perceived need for new regulation*, thus reducing the strength of that pathway when *seafood stocks* are healthy.

From the *community wellbeing* and *adequacy of management practices* nodes, influence is passed on round the same factor that have formed previous loops – through *fishing restrictions*, *catch* and *seafood stocks*.

Figure 35. The drivers of change – community satisfaction



7. Using the map to explore the anticipated dynamics of the system over time

The previous section described the system map as developed by participants in the workshops. This section outlines one process of using the system map to gain insight and develop understanding. This process is referred to here as *analogue simulation*.

7.1. Different ways of gaining insight from a system map

Section 4.6.1 described how system maps, like that described in this report, sit at the lower end of the spectrum of complexity for the use of System Dynamics tools. As you move up the spectrum of complexity small-scale simulation models can be developed, and eventually large-scale and complex simulation models.

Yet low complexity does not mean that only low levels of insight or stakeholder alignment are achieved. Often the opposite is true – significant insight and stakeholder alignment can be gained from participatory processes that developed system maps.

Insight can be achieved in a variety of ways, each building upon the other. All of these are subjective and are listed below:

1. At the very least, the system map helps visually demonstrate the interconnected nature of the system that is being mapped.
2. System maps also highlight the circular nature of causality, where it has been identified. This allows insight into how much of a system's behaviour comes from endogenous versus exogenous influence. This can help reframe participants perceptions of how much influence is from 'external' sources and how much is from 'within'.
3. Using the system map as a tool to guide discussion, the anticipated dynamic behaviour of some elements in the system can be discussed and explored as a group. Earlier, the development of the system map was anchored in discussing the trends of behaviour in the system up until this point in time (see section 5). At this point, the discussion is anchored around how the system may behave *from this point onwards*, effectively bringing the discussion back full circle to talking about trends over time.
4. This discussion of trends over time can be aided by the use of a technique referred to here as *analogue simulation*. This is effectively the same subjective discussion about what the dynamics of the system will do in the future, yet it is aided by the use of tangible counters for change (up or down) in specific factors of interest, within set time steps over a period of time. As this is a manual process of determining the changes in each factor, it obviously excludes the rigour of mathematic calculations so it is not intended as a substitute for mathematical modelling. However, it is intended as a an additional 'hands on' aid to increase insight and learning.

The process outlined in this section describes point 4 outlined above.

7.2. How analogue simulation was used

In this project analogue simulation was used as a *demonstration* of how the system map could be used by the HBMaC Group. Originally it was intended that process would be used at a point where there was wide attendance of HBMaC Group members and a long-list of possible interventions to discuss.

In reality this final workshop was undertaken as the COVID-19 pandemic was hitting New Zealand and at the time the country was at Level 2 precaution, meaning physical attendance of workplaces was discouraged and physical distancing was encouraged[4]. This meant that there were some participants who cancelled their workshop attendance and also that the facilitator had to handle all of the marbles for the day, so it was less 'hands on' than anticipated.

Also, the potential impact of these extenuating circumstances on the concentration and mental presence of some workshop attendees, while impossible to gauge, should not be underestimated.

Consequently, the scenarios outlined here were only hypothetical demonstrations of *how the tool could be used*. They are not considered actual results of the considerations of these interventions.

Rather, the final workshop and the results here should be viewed as an instructional guide to how the system map may be used to assist the HBMaC Group with discussions and decision-making in the future. The existing knowledge sources outlined in the following major section of this report (section 8) should also be considered as supplementary information that, along with this system map, can be used to support any discussions and recommendations made about future interventions or research.

7.2.1. Analogue simulation methodology

The methodology used for analogue simulation is outlined below in Table 1:

Table 1. Analogue simulation methodology

Methodology step	Description
Factors identified:	A group identifies a range of factors from the system map that they want to consider changes in. This number should be kept to a manageable amount (3-4 is good), too many and it becomes confusing to discuss. The names of these factors are put in the header of the columns in the data table below (Table 2).
Identify interventions to test:	A range of possible interventions are identified to consider and discuss.
System map & cups set up:	A large printout of the map is placed on a table. Clear plastic cups are placed on the map for each of the factors being discussed (and labelled if necessary).
Time steps agreed:	A consistent series of time steps, across which to consider change in the system, are agreed. The time steps are then written in the data table. For example, 5 year time periods, as per the example in Table 2.
Initial values determined:	An *initial value* for each factor is agreed as a starting point. This is intended to be a subjective reflection of what level each factor is at the time of beginning the analogue simulation. For example, if it is considered that there is currently a high level of something then a larger number is used; if something is considered to be diminished or at a low level, a low number is used. The number determined is represented by that number of marbles being deposited in each cup.
Determine scale of change:	The scale of possible change for each time step should be determined. In this case a scale of 0-3 was used. 0 = no change; 1 = a small amount of change; 2 = moderate change; and 3 = significant change.

[4] The final workshop was held on Wed 18 March 2020 when the country was on Level 2 alert. The intention to put the country into 'lockdown' (Level 4) at midnight Tuesday 23/ Wednesday 24 March was announced on Monday 22 March, as was an immediate move to Level 3 for the remaining time.

Methodology step	Description
Set a baseline:	An initial run of the analogue simulation is run under a ‘business as usual’ or ‘do nothing’ approach. This provides an indicative baseline against which other runs that include interventions can be compared. The group discusses how they expect the level of each main factor, represented by a cup, to change each time step. The feedback loops articulated in the system map are used to guide the conversation. These changes are recorded on record sheet (see Table 2). Once all relevant time steps have been completed, the results may be quickly graphed (in Excel or by hand) to provide prompt visual feedback to the group.
Simulate interventions:	Undertake a separate analogue simulation for each intervention (or combination of interventions) being considered. Note: If some interventions are in a specific geographical area that have significantly different baseline conditions that the baseline that has already been set, a new baseline for that area would be helpful to run.
Compare interventions:	The results of the analogue simulations are compared and the group discusses any insights that they gained from the process. This is used to inform their discussions and decisions.

The below table (Table 2) provides a template for how to capture results of an analogue simulation. The factors of interest are labelled across the top (the solid red outline). Time steps are outlined in the left hand column (the dashed red outline).

Table 2. Example table

Factor	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5		Factor 6		Factor 7		Factor 8	
	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total
Time step	Initial value	*I*	Initial value	*I*	Initial value	*I*	Initial value	*I*	Initial value	*I*	Initial value	*I*	Initial value	*I*	Initial value	*I*
0-5 years	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C
5-10 years	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C
10-15 years	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C
15-20 years	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C
20-25 years	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C
25-30 years	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C	*T*	C

Legend: Factor 1 ***= Factor name*** ***I = Initial value of factor***

0-5 years ***= Time step*** ***T = Change to that factor in that time step***

C = Cumulative value of factor

Under each factor label is a pair of columns. The left hand column captures the change in each factor at each time step (indicated by ‘T’); at the top of the right hand *cumulative total* column is a space for the *initial value* of a factor to be recorded (indicated by ‘I’); the balance of this column is where cumulative totals at each time step are recorded (indicated by ‘C’).

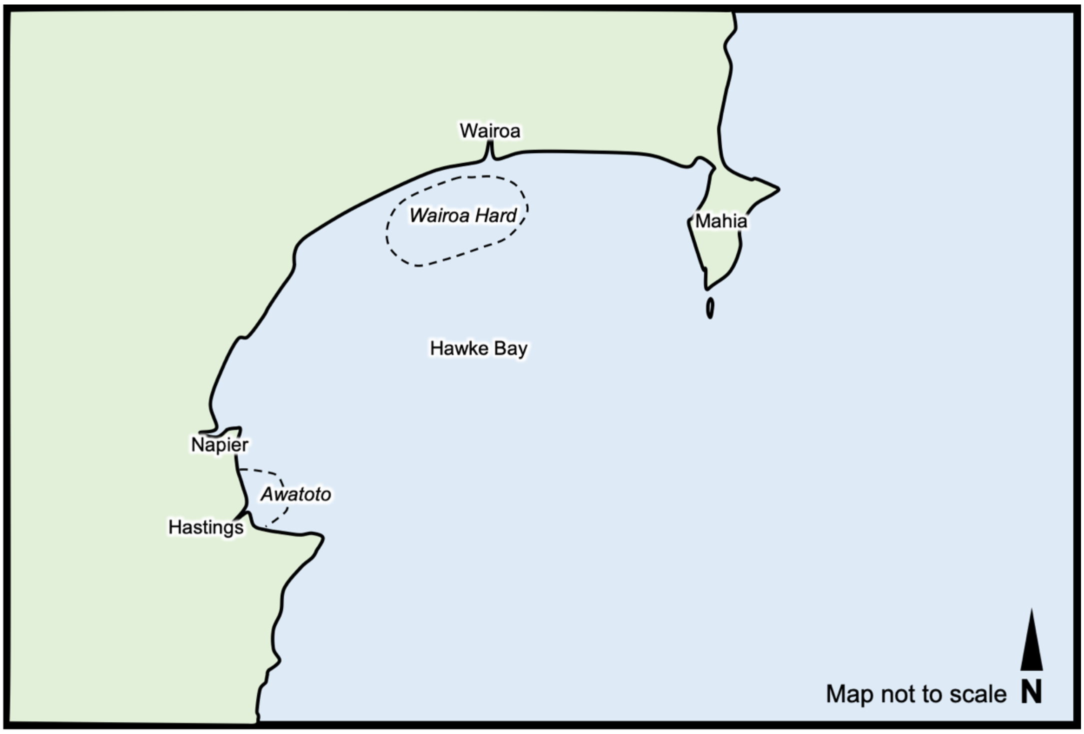
7.2.2. Analogue simulation scenarios

Three analogue simulations were undertaken (Table 3, Figure 36). Firstly, a 'baseline' example was set where a 'do nothing' approach was assumed and only the legacy effects of current or planned policies and/or projects were taken into consideration. Secondly, the real example of the closing of the 'Wairoa Hard' was discussed, and thirdly, a hypothetical example at Awatoto was discussed.

Table 3. Example scenarios used to demonstrate use of the system map with analogue simulation

Example scenario	Description
Hawke's Bay baseline	A hypothetical 'baseline' example was set. Here, a 'do nothing' approach was assumed and only the legacy effects of current or planned policies and/or projects were taken into consideration. For example, the impact of the Tukituki plan change and the TANK plan change. To set a baseline for comparison purposes, this was used as the first hypothetical demonstration of the tool. This was considered at an **aggregate 'all of Hawke's Bay'** level.
Continued closure of the Wairoa Hard	The 'Wairoa Hard' is an inshore area between the Moeanginagi and Wairoa river mouths. It is comprised of cobbly, 'foul' ground. It has been closed to commercial net fishing since 1981, due to its perceived role as a fish nursery. This scenario began now and includes the legacy impacts of the existing closure. It assumes an ongoing closure into the future. To demonstrate a specific local intervention, this was used as the second hypothetical demonstration of the tool. This was considered at a **localised Wairoa Hard area** only.
Mussel beds at Awatoto	Awatoto is an area located in the southern Hawke Bay that generally has less water movement that the 'Wairoa Hard', so it has a much larger deposited sediment and turbidity issue. It is located near the mouths of the Tukituki River as well as Tutāekuri and Ngaruroro Rivers and the Karamu Stream (from the TANK catchments). It is understood to be experiencing elevated nutrient discharges from legal municipal wastewater discharges. It is also heavily sedimented, but previously was an area with extensive mussel beds. To demonstrate a different type of local intervention, this was used as the third hypothetical demonstration of the tool. This was considered at a **localised Awatoto area** only.

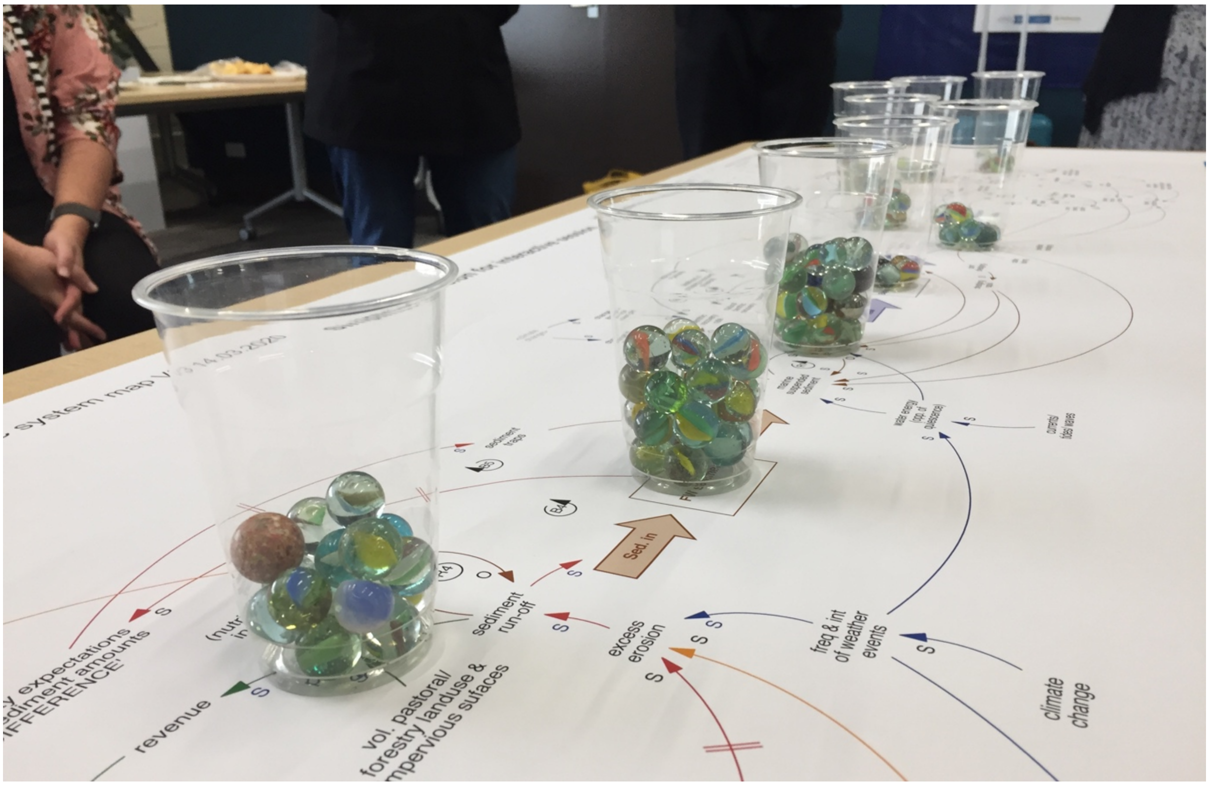
Figure 36. Conceptual map of Hawke Bay showing location of example scenarios



7.3. Analogue simulation results

This section outlines the analogue simulation results for the scenarios described previously. The following image (Figure 37) demonstrates the analogue simulation technique in action.

Figure 37. Demonstration of the analogue simulation method in action



7.3.1. Setting a Hawke's Bay baseline

The baseline example was considered for Hawke's Bay as a whole. The assumptions for initial values are shown in Table 4.

It assumed that there was a reasonable level of soil productivity (16); a large amount of freshwater sediments being discharged to the ocean and a high level of accumulated sediments in Hawke's Bay. Benthic structure was assumed to be low, given the historic degradation that had been discussed (see section 5).

The level of bottom contact was assumed to be moderate, primarily because there was still an amount of active trawling being undertaken in Hawke's Bay. Seafood stocks were also considered to be moderate but not as abundant as they were previously.

All fisher satisfaction was seen to be at a moderate level, particularly in order to reflect reasonable current levels of commercial and recreational fishing. Cultural identity was considered to be low, due to the historical decline this has experienced. Likewise, community wellbeing was seen to be low.

The six time steps were discussed and the below results were determined. It was assumed that fishing activity would continue as normal. It was also assumed that freshwater policy would continue to be rolled out across the various catchments in the region, as it had been in the Tukituki catchment and was being in the TANK[5] catchments, to meet the governments NPS-FM[6] requirements.

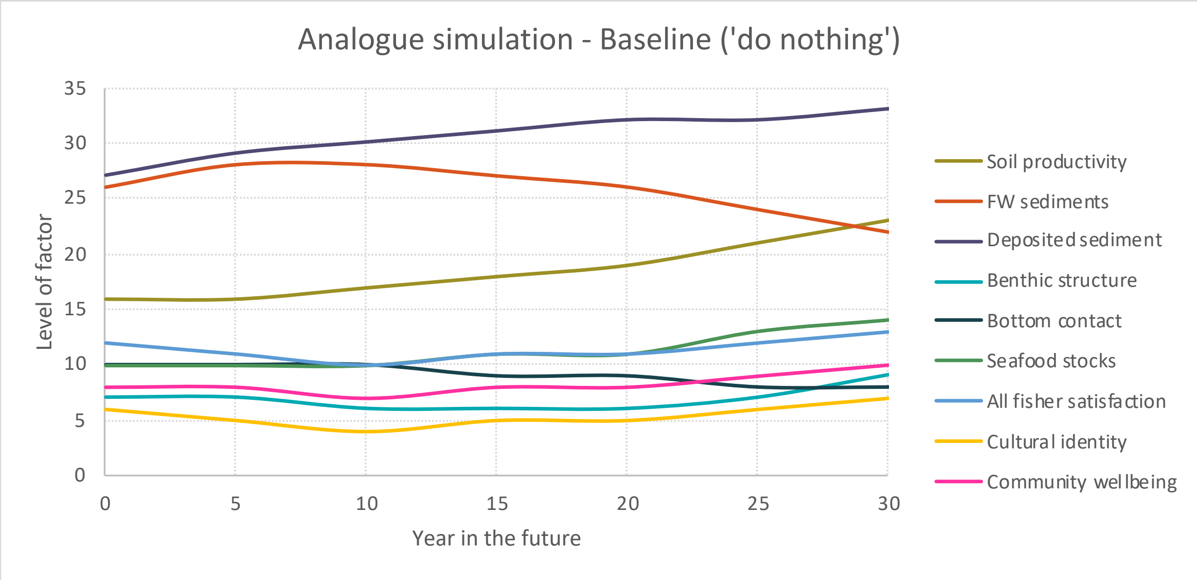
Table 4. Hawke's Bay baseline: scenario results

Factor	Soil productivity		FW sediments		Deposited sediment		Benthic structure		Bottom contact		Seafood stocks		All fisher satisfaction		Cultural identity		Community wellbeing	
	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total
Time step	Initial value	16	Initial value	26	Initial value	27	Initial value	7	Initial value	10	Initial value	10	Initial value	12	Initial value	6	Initial value	8
0-5 years	0	16	2	28	2	29	0	7	0	10	0	10	-1	11	-1	5	0	8
5-10 years	1	17	0	28	1	30	-1	6	0	10	0	10	-1	10	-1	4	-1	7
10-15 years	1	18	-1	27	1	31	0	6	-1	9	1	11	1	11	1	5	1	8
15-20 years	1	19	-1	26	1	32	0	6	0	9	0	11	0	11	0	5	0	8
20-25 years	2	21	-2	24	0	32	1	7	-1	8	2	13	1	12	1	6	1	9
25-30 years	2	23	-2	22	1	33	2	9	0	8	1	14	1	13	1	7	1	10

[5] TANK is an acronym for the four catchments included in this plan change: The Tutaekuri, Ahuriri, Ngaruroro and Karimu rivers.

[6] National Policy Statement for Freshwater Management (NPS-FM).

Figure 38. **Hawke Bay baseline: scenario trends**



When the group discussed these results, they identified the following insights as shown in Figure 38:

- Sedimentation (both freshwater sediments and deposited sediments) are obviously natural processes, but they are currently deemed to be out of balance with what is reasonably expected of the natural environment in Hawke's Bay.
- **Soil productivity** was assumed to grow. Currently it was likely to be more input based, but there was discussion that there may be a more popular movement towards organic or regenerative-style agriculture. There was already some of this established in the Hawke's Bay and the HBRC also recently established a fund to support alternative farming approaches. This is also in part due to the ongoing rollout of policy to meet the governments NPS-FM guidelines.
- **Freshwater sediments** are assumed to continue to grow for at least one 5 year time-step, before plateauing in the second time-step (5-10 years). Freshwater sediments are only assumed to decline beyond this period, slightly at first and more dramatically after 20 years. The behaviour demonstrated by this line on the graph was a good example of behaviour where there was a ***delay*** in an effect being realised. This is often referred to as 'worse-before-better' behaviour and serves to reinforce that effects can take significant time to manifest after a change is made.
- The *rate* at which **deposited sediment** accumulates in Hawke's Bay was expected to *decrease*, although the *total amount* of deposited sediment was still expected to *increase*, so long as there continued to be freshwater sediments deposited into Hawke's Bay. In short, this was still expected to be in excess of what the natural current and water movement in Hawke's Bay could reasonably be expected to disperse. It was also noted by participants that there was a huge legacy amount of deposited sediments in Hawke's Bay that these were added to. This was a good example of a ***legacy effect*** that the analogue simulation process was able to help people articulate and understand.
- It was thought that it would take some time before **seafood stocks** would begin to increase. This line shows a slow upward tick after 10 years, with a greater rise after 20 years. A major insight for the group was that the impact on this factor (and the others below) would be both ***delayed and not as pronounced***, as impacts on the other factors that were earlier in the causal chain (e.g. freshwater sediments and deposited sediments).
- **All fisher satisfaction**, **cultural identity**, and **community satisfaction** were all expected to continue to remain low, or even decrease further, before beginning to increase again. As with **seafood stocks**, these factors all also suffered from a ***delay*** effect from changes in the other factors and also a ***dilution of impact*** due to their distance from the original changes. While

they all ended up being higher than their initial values, they were not significantly higher. This highlighted to the group that any meaningful change was likely to take some time.

7.3.2. Continued closure of the 'Wairoa Hard'

The 'Wairoa Hard' is an inshore area between the Moeanginagi and Wairoa river mouths comprised of cobbly, 'foul' ground. It has been closed to commercial net fishing since 1981, due to its role as a fish nursery.

For this analogue simulation several factors were removed. This was partly to make it more manageable in the time allowed, and also partly because there was a realisation that many of the wellbeing factors (**all fisher satisfaction**, **cultural identity** and **community wellbeing**) all tended to experience similar behaviours.

Deposited sediments were removed because it is known that water movement and currents are stronger in this area, and there is not a large amount of deposited sediments there. **Bottom contact** was removed as this area was closed to commercial trawling. **Community wellbeing** was removed due to it being likely to be reflected in **all fisher satisfaction** and **cultural identity**.

All initial values remained the same with the exception of **Benthic structure** which was increased from 7 to 14. This reflected the fact that the area had been closed for some time already and recent survey work has indicated some recovery in kelp growth.

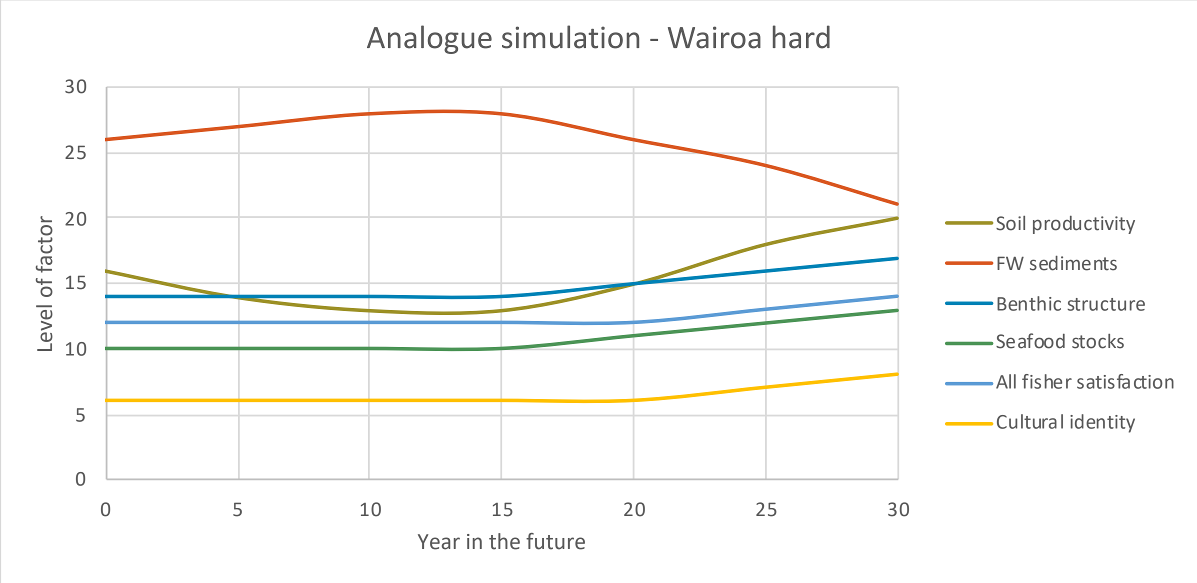
Apart from this minor change in starting conditions, all other assumptions from the baseline example were assumed to also be at play – e.g. the ongoing roll out of freshwater policy to meet NPS-FM requirements.

The results for this analogue simulation are shown in the table and graph below.

Table 5. Continued closure of the 'Wairoa hard': scenario results

Factor	Soil productivity		FW sediments		Benthic structure		Seafood stocks		All fisher satisfaction		Cultural identity	
	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total
Time step	Initial value	*16*	Initial value	*26*	Initial value	*14*	Initial value	*10*	Initial value	*12*	Initial value	*6*
0-5 years	*-2*	14	*1*	27	*0*	14	*0*	10	*0*	12	*0*	6
5-10 years	*-1*	13	*1*	28	*0*	14	*0*	10	*0*	12	*0*	6
10-15 years	*0*	13	*0*	28	*0*	14	*0*	10	*0*	12	*0*	6
15-20 years	*2*	15	*-2*	26	*1*	15	*1*	11	*0*	12	*0*	6
20-25 years	*3*	18	*-2*	24	*1*	16	*1*	12	*1*	13	*1*	7
25-30 years	*2*	20	*-3*	21	*1*	17	*1*	13	*1*	14	*1*	8

Figure 39. Continued closure of the 'Wairoa Hard': scenario trends



In general, this analogue simulation demonstrated broadly similar results to the baseline as shown in Figure 39, with a few slight difference worth noting:

- **Soil productivity** was seen as reducing further than the region as a whole, before levelling off and recovering. This tended to be accounted for by the fact that there were not yet any freshwater policies being developed for the Wairoa catchment, and the catchment had some significant soil productivity issues already (it is predominantly forestry rather than pastoral).
- **Freshwater sediments** are expected to continue to increase for several time periods, before plateauing and beginning to decrease. These would decrease dramatically as soil productivity increases.
- The inter-relationship of these two factors above, mirrors that of the baseline. Both presenting as a delay and 'worse-before-better' behaviour.
- **Benthic structure** and **seafood stocks** are both expected to remain constant for a while, but to increase when soil productivity improves and sediment loads reduce. While gains have been made to date due to the closure of the area to commercial trawling, it is expected that the continue sediment load and resulting turbidity will continue to constrain the recovery of **benthic structure** and therefore **seafood stocks**.
- **All fisher satisfaction** and **cultural identity** also remain constant at existing lower levels. There is expected to be a slight increase in these levels, but not until the longer-term (beyond 20 years). These small increases highlight the ***delayed and diluted impact*** of changes that occur elsewhere in the system, hinting at the time required for recovery.

7.3.3. Mussel beds at Awatoto

For the third simulation, the hypothetical example of Awatoto was used.

Awatoto is an area located in the southern Hawke Bay that generally has less water movement that the 'Wairoa Hard', so it has a much larger deposited sediment and turbidity issue. It is located near the mouths of the Tukituki River as well as Tutāekuri and Ngaruroro Rivers and the Karamu Stream (from the TANK catchments), therefore it is likely to already be experiencing, or soon to experience, the impacts of freshwater policies operative or drafted in these areas.

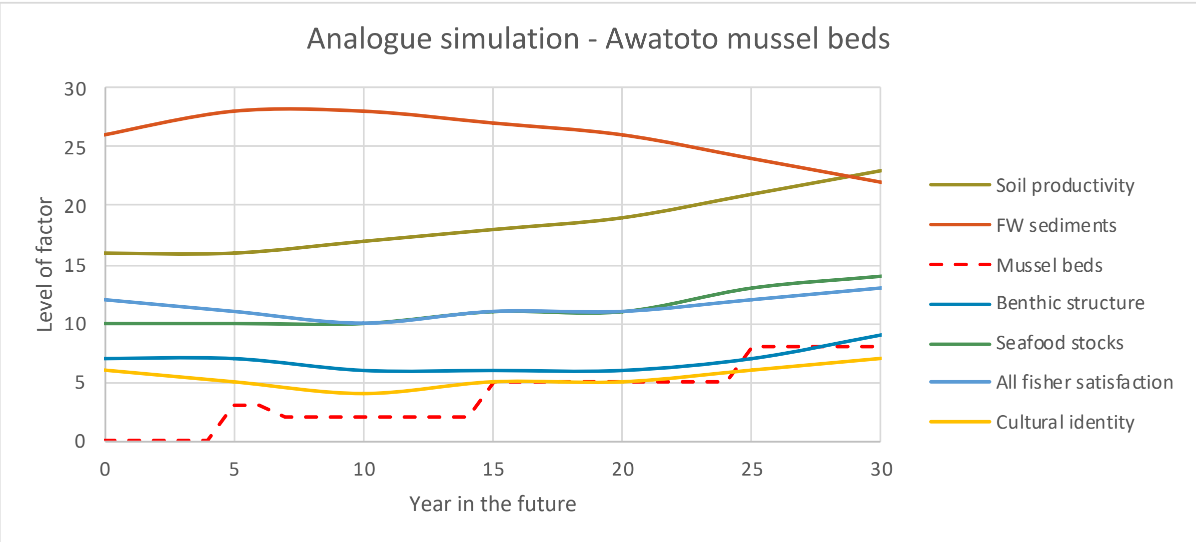
It is understood to be experiencing elevated nutrient discharges from legal industrial municipal wastewater discharges in that area. It is also heavily sedimented and workshop participants understood it to historically be an area with lots of mussel beds.

This intervention seeks to wait for a period of time (5 years) for the effect of freshwater policies to be felt, then seed the area with a series of man-made mussel beds. This would occur in years 5, 15 and 25. Given other potential nutrient contamination issues, it is not expected that the mussels will be edible in the first instance (if they were to establish), but it is expected that they would begin to filter the water. Over time, if the other contamination issues were dealt with, it would be anticipated that the mussels would become edible.

Table 6. Mussel beds at Awatoto: scenario results

Factor	Soil productivity		FW sediments		Mussel beds		Benthic structure		Seafood stocks		All fisher satisfaction		Cultural identity	
	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total	Change per time step	Cumulative total
Time step	Initial value	*16*	Initial value	*26*	Initial value	*0*	Initial value	*7*	Initial value	*10*	Initial value	*12*	Initial value	*6*
0-5 years	*0*	16	*2*	28	*0*	0	*0*	7	*0*	10	*-1*	11	*-1*	5
5-10 years	*1*	17	*0*	28	*3*	3	*-1*	6	*0*	10	*-1*	10	*-1*	4
10-15 years	*1*	18	*-1*	27	*0*	3	*0*	6	*1*	11	*1*	11	*1*	5
15-20 years	*1*	19	*-1*	26	*3*	6	*0*	6	*0*	11	*0*	11	*0*	5
20-25 years	*2*	21	*-2*	24	*0*	6	*1*	7	*2*	13	*1*	12	*1*	6
25-30 years	*2*	23	*-2*	22	*3*	9	*2*	9	*1*	14	*1*	13	*1*	7

Figure 40. Mussel beds at Awatoto: scenario trends



Again, the general patterns of this analogue simulation are similar to the baseline, as shown in Figure 40, with some subtle differences.

- **Soil productivity** was expected to increase after the first time step, mostly due to the fact that the Tukituki plan change is already in place and the TANK plan change has been notified.
- **Freshwater sediments** are expected to peak earlier than in the Wairoa example, then decline, for similar reasons.
- It was not expected that the first seeding of **mussel beds** would necessarily thrive and they may not even survive or grow particularly large. For this reason, the level of mussels is shown

as declining slightly over the first 10 years, after the first seeding. However, if some did survive, they could be expected to contribute to the reducing turbidity and therefore, consequently, a return of **benthic structure**. This combined with the changes in the other factors would help improve **benthic structure**.

- Longer term, the above would help to contribute to improved **seafood stocks**.
- Given the low state of **all fisher satisfaction** and **cultural identity** currently, these were anticipated to further decrease before improving. Again, signs of ***delay*** in 'worse-before-better' behaviour were observed, and ***dilution*** of the impact from other causal factors by the time the impact reached this area. Overall, **all fisher satisfaction** and **cultural identity** were expected to be similar or only slightly improved on where they were now, although they would by then be trending in a more positive direction.

8. Knowledge stocktake

Having developed and described the system map developed by the HBMaC group in the previous sections, this section attempts a relative 'stocktake' of knowledge held about the various factors and feedback loops identified in the map. The term 'knowledge' is used to respect and include various forms of knowledge, this includes 'western' science, mātauranga, and community knowledge from a variety of sources.

Drawing together these various sources of knowledge is in itself a useful exercise. Yet once collated, the challenge of attempting to understand the completeness or usefulness of these various sources of knowledge remains.

To help assess this, a subjective 5-point scale was developed against which the various sources of knowledge and science were considered. This scale rated data quality as Very High (VH); High (H); Medium (M); Low (L); or Very Low (VL). This scale is intended as an attempt at categorising the integrity of data from various knowledge sources and is described in Table 7.

Table 7. Knowledge and science quality scale

Data quality	Description
VH	This indicates a **very high** level of **data quality AND availability**. Data is highly robust and it is available for all areas that it is required. Longitudinal data is also available if required, to provide temporal context and robustness. This applies to data from a range of knowledge sources.
H	This indicates a **high** level of **data quality AND/OR availability**. Data is fairly robust and it is available for most areas that it is required, or at least a reasonable selection. Some longitudinal is also available to draw on, although it may not be in preferred sampling steps. However, it does provide some temporal context and robustness. This applies to data from a range of knowledge sources.
M	This indicates a **medium** level of **data quality AND/OR availability**. Data is available and it is moderately to fairly robust. However, it is more likely to be discrete than available for the areas that it is required. Historical data may be available, but it is also likely to be discrete and inconsistent. Strong anecdotal evidence or experience may provide useful context here. This applies to data from a range of knowledge sources.
L	This indicates a **low** level of **data quality OR availability**. Any available data is unlikely to be robust. It is more likely to be anecdotal evidence or experience. It is only available in discrete samples and not for all of the areas that it is required. Some historical data may be available, but it is scarce, likely to be discrete and inconsistent. This applies to data from a range of knowledge sources.
VL	This indicates a **very low** level of **data quality OR availability**. Any available data is very unlikely to be robust and almost entirely anecdotal evidence or experience-based. Occasional discrete samples are the norm and it is not widely available in the areas that it is required. Historical data is scarce, discrete and anecdotal. This applies to data from a range of knowledge sources.

This scale sought to recognise that the various sources of knowledge and science were diverse and much of it was qualitative or anecdotal, all of which was useful. In order not to bias the scale to quantitative or science-based data, the following two criteria were considered important, as was their ability to be applied to both quantitative and qualitative data:

- **Robustness:** The source of knowledge and the way in which it was acquired or collected, is considered reliable and robust. This extended from circumstantially anecdotal or experience-based (Very Low (VL)); through to obtained in a highly methodical and reliable way – regardless of whether it was quantitative, qualitative or experiential data (Very High VH)).
- **Availability (geographically or temporally):** The geographical or temporal diversity and availability of the knowledge. This extends from discrete and isolated physical location data, and/or information from a single point in time (Very Low (VL)), to consistent data available across a wide variety of physical/geographical locations, and/or a consistent longitudinal data set (Very High (VH)).

Areas of knowledge or science are firstly grouped by a communal shaded area on the system map, which are each labelled with a number, then the quality scale is applied. An example of how this scale may be applied is shown below in Table 8.

Firstly, the area of the system map that it applies to is noted (**No. on map**); then the factors covered by this shaded area are listed (**Factors on map**); the type of knowledge or science is described, as is its source (**Knowledge type (and source)**); the data quality is then rated from very high to very low (**Data qual. VH – VL**); and finally comments capture summary details of this knowledge or science and any reasoning for the rating (**Comments**).

Table 8. Example showing how knowledge is rated for quality

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
#	**Example factor**	Type of knowledge (knowledge source – e.g. organisation)	VH; H; M; L; or VL	Contextual description or comments.

8.1. Knowledge of freshwater sediments and benthic structure

This section deals with the knowledge of the freshwater sediments and benthic structure part of the system map (the central part).

Figure 41. Quality of knowledge around the freshwater sediments and benthic structure

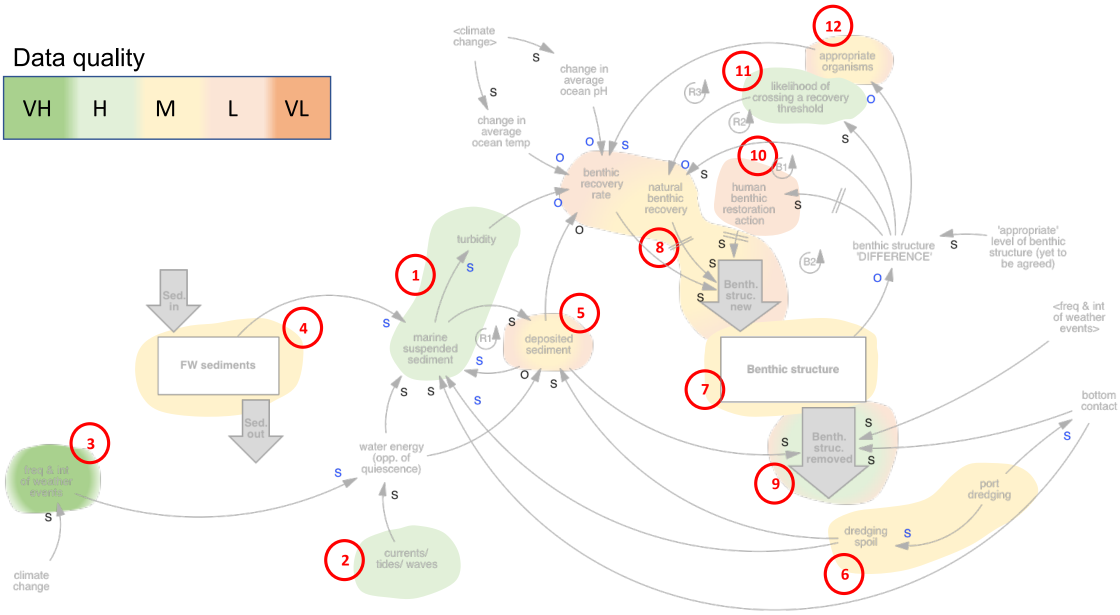


Table 9. Quality of knowledge around the freshwater sediments and benthic structure

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
1	**Suspended sediment & turbidity**	State of the Environment (SOE) reporting (HBRC)	H	12 years of SOE reporting data.
		Chlorophyll-a satellite data (HBRC)	H	Data recorded in-situ for 8 months from 2012-2013. Satellite data from 2002-2013.
		Water column productivity, particulates, etc. (NIWA)	H	NIWA's glider mission 2019 Recorded temperature, salinity, chlorophyll-a, dissolved oxygen, and coloured dissolved organic matter
		Water quality buoys (Mahia Māori Committee)	future	Water quality buoys are currently being set up along the river near Mahia. In the future this will contribute to an overall database of ecosystem health.
2	**Current/ tides/ waves**	Current information through water column Acoustic Doppler Current Profiler (ADCP) at Hawke's Bay Water Quality information (HAWQi) (HBRC)	H	ADCP attached to bottom of HAWQi buoy and records current speed and direction at 2, 10, and 16 meters (since 2012)
		Wave height and direction Port wave buoy (Napier Port)	H	Measures wave height and direction twice an hour (since 2000)
		National scale representations of oceanography. MetOcean (MetService) is lead agency.	M	The Moana backbone model is a 25 year hydrodynamic hindcast model of New Zealand waters. An MBIE Endeavour funded project. One of the things it is doing is creating national scale representations of oceanographic dynamics. Beta version is currently available. Regional scale will be developed in upcoming years.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Information on the impact on water movement by consented activities. (HBRC)	L	Pan Pac consent to discharge (measured with ADCP) Port consent for dredging includes ADCP data
3	**Freq & int of weather events**	Regional weather information (MetService and NIWA regional weather stations)	H	NIWA hosts the CliFlo database which provides direct data downloads from climate observation stations across New Zealand, including stations managed by NIWA, MetService and other providers. Stations in the Hawke's Bay region: include Mahia, Napier airport, Cape Kidnappers, Cape Turnagain; data can be downloaded from https://cliflo.niwa.co.nz/pls/niwp/wgenf.genform1_proc These measure rainfall, wind speed and direction, temperature and humidity. Roughly 5-10 in the region.
		Regional weather and some soil information HBRC weather stations (HBRC)	VH	Climate stations record: - Soil Moisture - Soil Temperature - Potential Evapotranspiration (PET) - Air Temperature - Humidity - Solar Radiation - Wind Speed - Wind Direction - Rainfall Been recording since 2009 and there are roughly 20 around the region
		Habitat data includes tides, currents, and wind (Commercial fishers)	M	It is understood that fishers keep personal records of these things in the ocean. Will be dependent on personal record keeping.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
4	**Freshwater sediments**	Freshwater sediment load data. SOE reporting (HBRC)	M	Low level of knowledge due to low sampling. Suspended sediment auto-samplers are set up for time proportional of flow proportional data for single events. It appears Tukituki FW sediment loads are highly under-estimated. This is only measured during a high rainflow/flow event, not on an ongoing basis.
		Predicted erosion and sediment loads. Manaaki Whenua | Landcare Research (MWLR). Our Land and Water National Science Challenge	future	HB project OLW NSC project in development. Will be in the Wairoa catchment, development of a model to predict land management effects on erosion and sediment yield (using SedNet model). https://www.landcareresearch.co.nz/publications/newsletters/soil/issue-21/sednetnz
		Possible information on freshwater sediment loads associated with maps. Land Information New Zealand (LINZ)	??	Suggested by participants as they may have relevant info with maps. This is assumed, needs to be confirmed.
		Consent compliance data associated with major infrastructure. HBRC	L	For example, compliance work for storm water consent for NCC in estuary (suspended solids). Only triggered with enough rain so patchy.
5	**Deposited sediment**	Various sub-tidal samples from around Hawke's Bay (HBRC & NIWA/Ocean Data Network)	M	NIWA/Ocean Data Network: The Ocean Data Network is an international collaboration collecting data worldwide, NIWA is the NZ rep (https://nzodn.nz/). Collects all oceanographic data, including sediments – assumed to draw on many of the other sources listed in these tables). HBRC: These are only surface samples (up to 2cm deep) as they look to characterise the surface. Not longitudinal, only discrete and occasional. (HBRC samples from 2017-2019).
		Various inter-tidal samples from some estuaries (HBRC)	M	There is some data from long-term monitoring sites within some estuaries. Length of sampling time varies (some estuaries added over time), but longest time series from 2006-present.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Habitat data possibly including information on benthos or benthic structure. (Commercial fishers)	L	Some fishers may have historic data from their own records of benthos trawl catches, of what was brought up from the benthos or benthic structure.
		Information from consent compliance monitoring. (HBRC)	L	Consent compliance: • Pan Pac – Tangoio • Port – Westshore • NCC – outfall • HDC
		Port-Marine Cultural Health (Napier Port and others)	future	Measuring sediment from dredging onto Pania reef. Measuring rate of sediment deposition in cray holes for whanau to understand sedimentation.
6	**Port dredging & dredging spoil**	Compliance monitoring information (HBRC)	M	Information will be held in-house by HBRC on their compliance files.
		Turbidity data (Napier Port)	M	Turbidity buoys - Live online now
7	**Benthic structure**	Multibeam surveys (NIWA)	H	• Back scatter multibeam surveys: indicating whether the ocean floor is gravel or rock, shell or mud. • Water column back scatter multibeam surveys: indicating whether the things in the water column are kelp beds, fish or an aggregation.
		Remote operated vehicle (ROV) data (HBRC)	M	This activity was to 'ground-truth' the multibeam surveys. Human analysis is undertaken of the ROV video footage (to characterise the recorded habitat).
		Abiotic and biotic habitat data (HBRC)	M	This is based on interviews by Haggitt and Wade for the marine review

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Habitat data possibly including information on benthos or benthic structure. (Commercial fishers)	L	Some fishers may have historic data from their own records of benthos trawl catches, of what was brought up from the benthos or benthic structure. Info from fish brought on board (gutted or photographs of stuff expelled from stomach) – recreational fishers know exactly where fish from/commercial fishers know general area. Fisherman would also have maps of the benthos in general. Could put together picture from plotter data
		Information from observer trip reports (MPI)	M	Observer trip reports (20-30 in last 5 years)
		Discrete historical information about benthic habitats. (MPI)	L	80s report in house on benthic habitats (Alan Kilner) – was used in Haggitt and Wade report. Might be this: Kilner, A. R., Ackroyd, J. M. (1978) Fish and invertebrate macro-fauna of Ahuriri estuary, Napier. New Zealand Fisheries Management Division. Fisheries technical report 153, 79 p.
		NZ specific (national scale) environmental classifications based on environmental variables. (MfE, NIWA, DOC)	M	MfE funded a Marine Environments Classification report, seeking to categorise and group similar ocean habitats around NZ. First version c.2006. Only included environmental variables as drivers. This will be replaced/updated by a report currently in print. This is the Seafloor Community Classification, funded by DOC, NIWA is the lead agency. This will be based on environmental variables as drivers, as well as four biodiversity datasets.
		Detailed information of reef near Pan Pac operation. (HBRC)	L	For Pan Pac consent – map created of unnamed rocks around Tangoio. Good reef area. L because it is localised and one-off.
		Discrete data on benthic structure in some places. (DOC)	L	• A side-scan map of benthos around marine reserve (one off in 2005). • Report on seagrass percent cover following land slip (2019) • Patchy monitoring data of fish, lobster, kina, paua from 1995-2007 (none since then)

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Benthic community structure/abundance and nutrient fluxes. (NIWA)	M	MBIE project, subset of data published in Rodil et al. (2013) on indices of ecosystem health. 9 replicates at one site just landward of mouth of estuary. Data includes macrofaunal community structure and abundance, sediment characteristics, contaminants, and nutrient fluxes.
		Shellfish and commercial bycatch monitoring (Mahia Māori Committee)	future	Shellfish and commercial bycatch monitoring programmes are being set up to help determine benthic structure and health around Mahia. While not going yet, these may be a valuable source of information in the future.
8	**Benthic structure new**	Benthic structure response curves (Sustainable Seas NSC)	M	Some benthic structure response curves for some types of structure were developed in Sustainable Seas Phase I.
		SOE data (HBRC)	L	Some SOE data may be able to provide information here. E.g. sea grass data.
		Resource consent studies (HBRC)	L	Some benthic studies are likely to have occurred in relation to consent applications. e.g. dredge spoil and follow up studies (discrete). e.g. studies for outfalls (ongoing – may give insight to recovery rate?).
		Experiential data from a Paua translocation programme (Mahia marae)	L	There is currently a programme that translocates paua into the mataitai.
		Ramp survey data (Legasea)	M	Springs Box closure area 3 months a year (Dec-Feb) – ramp survey data confirms difference in fish takes. 13 year of data.
9	**Benthic structure removed**	Trawl line footprint records (MPI)	H	MPI only have the previous 10 years with both trawl start and endpoints. May be institutional and anecdotal historic knowledge, e.g. it is known that seaweed was 'mowed' on the Wairoa Hard. Wairoa Hard stripped of *Ecklonia* (seaweed) beds after 1970

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		MPI research on 'naturalness' of ocean floor after multiple trawls (MPI)	future	This information will depend on the habitats and depths that are modelled. This research has been commissioned, with results anticipated in late 2021.
		Experiential data (Māori)	L	Examples: Mussel reef lost at Maraetotara because covered in sediment from river. Horse mussels lost at Westshore beach (possibly from dredge spoil?).
10	**Human restoration action**	*Ficopomatus enigmaticus* removal (HBRC)	L	This is primarily 'low' because little of this activity has occurred. Some data has been collected in relation to removal of pest worms in Ahuriri Estuary and the recovery has been monitored (but not analysed).
11	**Likelihood of crossing a recovery threshold**	Information about tipping points in ecosystem structure, function & services (Sustainable Seas NSC)	future	Another project in Sustainable Seas is looking at tipping points. Empirical research to quantify stressor interactions and impacts on ecosystem structure, function and services. The key stressors are sediments, fishing (bottom contact) and nutrients.
		Benthic structure response curves (Sustainable Seas NSC)	H	Some benthic structure response curves for some types of structure were developed in Sustainable Seas Phase I. This was noted above and also links here. Curves available for 8 functional groups ranging from bioturbators to biogenic structure. Stressors response curves are for sediment loading and bottom contact fishing.
12	**Appropriate organisms**	Historic knowledge of what 'should be' in Hawke's Bay. (Haggitt and Wade review) (Mātauranga)	M	Haggitt and Wade developed a reasonable understanding of what 'should be' in the Hawke's Bay marine environment. This was based on anecdotal knowledge. This knowledge may be contributed to by mātauranga knowledge, which may measure change over time as well as what is expected.
		Possible data on benthic organisms in spoil from port dredging. (Cawthron)	unknown	Dredge data where port dumping dredge spoil to get info on benthos – HBRC may have this data for the Port's consent

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Experiential data of catch (Commercial fishers)	M	Trawling data of what's been caught in net with target fish species (Rick has it since 2007). Could look through Karl Warr's live camera footage.
		Possible information from trawl data (Commercial fishers)	L	Fisherman have habitat maps over time to figure out where to trawl. May have recorded anecdotal data of organisms in trawl nets. Rated L due to dependence on personal records.

8.2. Knowledge around land-based factors

Figure 42. Quality of knowledge around land-based factors

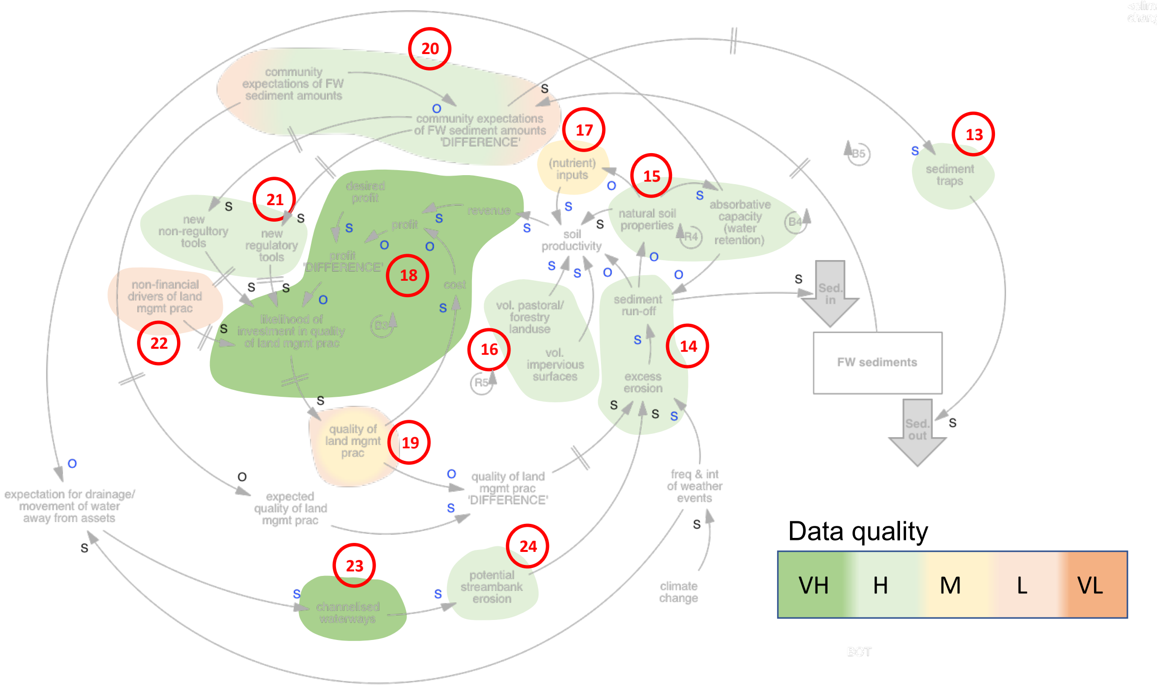


Table 10. Quality of knowledge around land-based factors

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
13	**Sediment traps**	Product performance information (supplier)	H	Where sediment traps or managed wetlands are constructed using specific products, much of this information will be available in the technical specifications of such products. It is expected that much of these will have been through product testing.
		Academic literature (various)	H	There is large amount of peer-reviewed academic literature on this type of intervention. Yet it is unlikely to be based on examples specifically from this area.
14	**Excess erosion/ sediment run-off**	Erosion and sediment run-off data SedNet model (MWLR)	H	The SedNet model is a model based on catchment characteristics. It is owned by Manaaki Whenua | Landcare Research.
15	**Natural soil properties & absorptive capacity (water retention)**	Spatial soil type database S-Map (MWLR)	H	Comprehensive, quantitative soil spatial information system to support sustainable development and scientific modelling.
		Land Use Capability rating (LUC) (MWLR)	H	A Land Use Capability (LUC) rating of the ability of land to sustain agricultural production, based on an assessment of the inventory factors of: climate, the effects of past land use, and the potential for erosion. https://lris.scinfo.org.nz/layer/48076-nzlri-land-use-capability/
16	**Vol. pastoral/ forestry landuse & vol. impervious surfaces**	National landscape classification Landcover database (LCDB) (MWLR)	H	The New Zealand Land Cover Database (LCDB) is a multi-temporal, thematic classification of New Zealand's land cover. It contains 33 mainland classes (35 including the offshore Chatham Islands).
17	**(nutrient) inputs**	Farm management tool Overseer (AgResearch)	M	OVERSEER is a farm-scale nutrient management tool, one of a growing number of on-line tools supporting New Zealand farmers to farm better. The use of Overseer remains widespread but with some limitations. However in the absence of a better tool, this is considered a 'best we've got'. Therefore, rated as an M.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Farm Management Plan's (FMP) (farmers/HBRC)	M	FMPs are often required for many farms in catchments where freshwater policy has been developed. Where these exist, they are likely to be based on Overseer modelling. This is only a sub-set of catchments across the region, so is not going to be a complete data set.
18	**Land use revenue and cost loops**	Industry and farm-level financial data collected by Industry groups. (various e.g. DairyNZ, Beef & Lamb, Forestry NZ)	VH	It is understood that various industry interest groups have a good level of financial information on various land-use activities. While this information is unlikely to be public, it may be able to be provided in aggregate or average form.
19	**Quality of land management practice*** * relates to the quality of the implementation of the practice on farm, rather than its proven efficacy. So, academic literature is excluded here. We are interested in the extent that interventions are practiced.	Farm Management Plan's (FMP) (farmers/HBRC)	M	FMPs are often required for many farms in catchments where freshwater policy has been developed. Where these exist, they are likely to be based on Overseer modelling. This is only a sub-set of catchments across the region, so is not going to be a complete data set.
		Survey of farmer land use practices and values Survey of rural decision makers (MWLR)	M	A longitudinal survey run every other year since 2013. This may have insights into the actual quality of practices applied on land, although this has yet to be tested.
		Catchment fencing data (HBRC)	L	Data collected when HBRC put in a fence or assist a landowner in putting in a fence. If fencing put up independent of HBRC, no record of it.
20	**Community expectations factors**	Resident surveys (HBRC)	L	Biennial survey to ascertain Hawke's Bay resident's attitudes towards the environment and awareness/satisfaction of HBRC's work. Only partly touches on what resident's value.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		NPS-FM and political debate (current and previous governments)	H	While anecdotal in nature, the strong presence of freshwater quality in the political debate in NZ for the last several decades, is testament to the expectations here. Also, the fact that the National Policy Statement on Freshwater Management has been revised several times in the last 10-15 years provides further evidence for this too. Although the actual 'level' of expectations are not be able measured, a dramatic improvement inferred.
21	**New regulatory tools and non-regulatory tools**	Assorted plans and planning guidance (various regional councils and government guidance)	H	There are a range of regulatory tools being used all around the country in various planning documents. There is also guidance from the government in terms of National Policy Statements.
		Academic papers and research on planning tools (various)	H	There is a rich literature on regulatory tools, including many in New Zealand. There is also likely to be industry research and/or guidance from organisations like the NZ Planning Institute (NZPI).
22	**Non-financial drivers**	Resident surveys (HBRC)	L	Biennial survey to ascertain Hawke's Bay resident's attitudes towards the environment and awareness/satisfaction of HBRC's work. Only limited inclusion of non-financial drivers.
23	**Channelised waterways**	Infrastructure data (HBRC & TLAs)	VH	GIS data on where channelised waterways are located.
24	**Potential streambank erosion**	Erosion and sediment run-off data (MWLR)	H	The SedNet model is an erosion and sediment run-off model based on catchment characteristics. It is owned by Manaaki Whenua | Landcare Research.
		Maps of inundation areas; hazards or risks. (HBRC & TLAs)	H	There would be good data on the flood protection schemes held by HBRC. There would be stormwater conveyance maps outlining overland flow and pipes that convey stormwater in assorted managed waterways systems. Held by HBRC and possibly TLA's.

8.3. Knowledge around marine-based factors

Figure 43. Quality of knowledge around marine-based factors

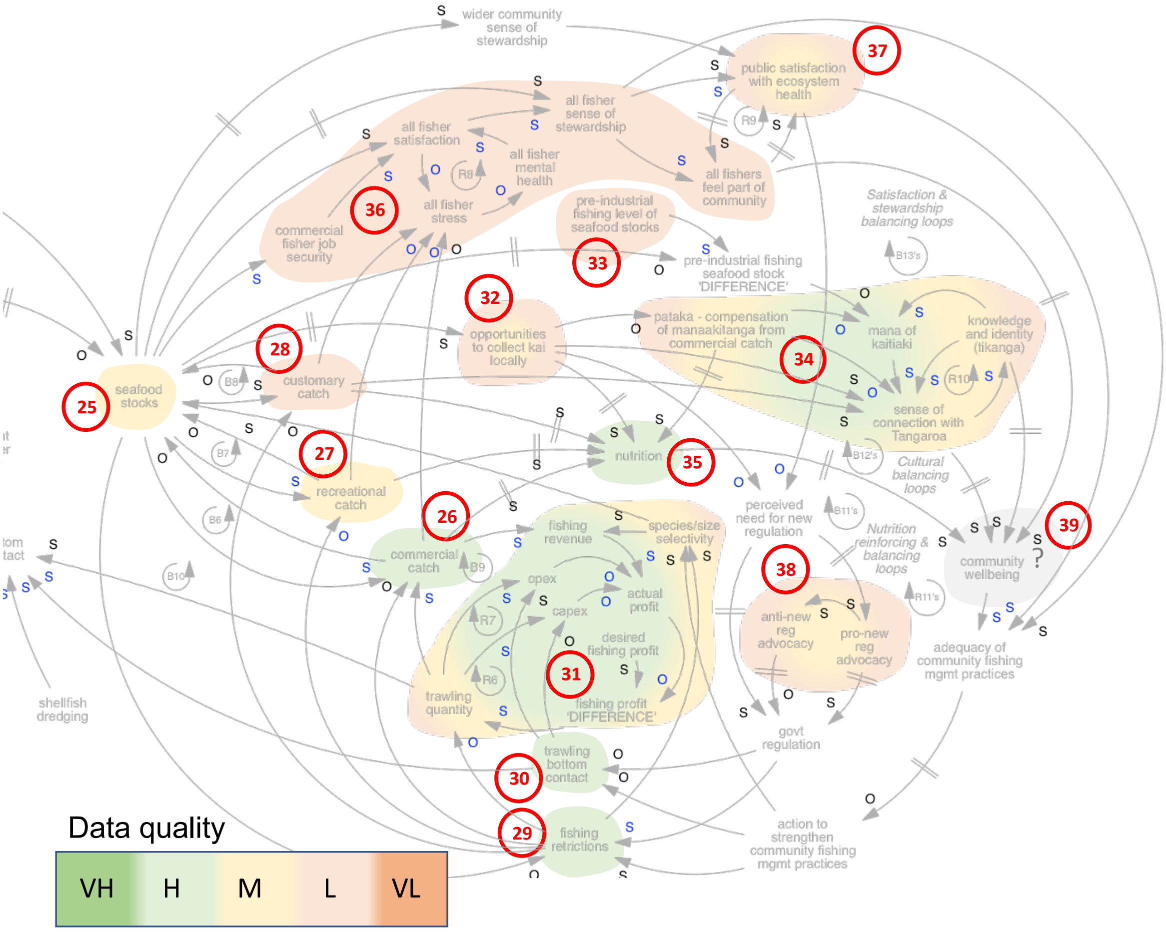


Table 11. Quality of knowledge around marine-based factors

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
25	**Seafood stocks**	Fisheries stock assessments Fisheries Assessment reports Fisheries NZ (MPI)	M	MPI has modelling and data that estimate fish stock populations and spawning biomass. Is species specific and unlikely to include non-fished species. Rated as M due there only being Tarakihi stock assessments in the HB.
		Anecdotal data (Haggitt and Wade HB Marine Review) (Commercial fishers)	M	Interviews on historical and observed fish stock trends (e.g. small trevally at the moment)
26	**Commercial catch**	Commercial catch records Fisheries NZ (MPI)	H	Commercial fishers must report their catch and position electronically. Includes landed species, non-fish or protected species, fish not landed, etc. Records exist for 30+ years.
27	**Recreational catch**	Recreational fishing surveys Fisheries NZ (MPI)	M	• National survey • Web cam for assessment reports • Aerial overflight survey for effort (# vessels out fishing)
		Recreational fishing surveys (Legasea)	M	13 years of ramp survey data from fishing club
28	**Customary catch**	Customary catch records Fisheries NZ (MPI)	L	While there is a quarterly requirement for customary catch data to go back to MPI for gazetted rahui, it is largely focused on shellfish and can be patchy. There is also data on some non-gazetted areas which is even more patchy. Not sure if this information is summarised after collection.
29	**Fishing restrictions**	QMS restriction information (MPI)	H	Records for QMS for c. 30 years.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Rahui and Mataitai information and locations (HBRC & Iwi)	H	Iwi will be able to provide knowledge of the rahui they have placed over time. HBRC has a GIS layer that shows all the mataitai.
30	**Trawling bottom contact**	Information on fishing practices Fisheries Inshore New Zealand (FINZ)	future	Report by Steven Eayrs summarizing gear modifications to improve contact with bottom. http://www.sesafe.com.au/
		Gear modification studies (NIWA/FINZ)	M	Local fishers, Fisheries Inshore New Zealand (FINZ) and NIWA have collaborated on a number of innovative trawl gear trials in the Hawkes Bay region, to reduce the bycatch of juvenile fish and/or unwanted species and reduce benthic impact. These trials have included comparisons of different cod-end mesh configurations, maintaining the trawl doors above the seabed, and a completely new rigid meshed cage cod-end. The later project has been continued by NIWA within an MBIE funded Smart Idea developing an automatic fish identification and drafting gate system to exclude unwanted catch.
		Trawl footprint studies (MPI)	H	MPI funds an annual trawl footprint. This and other fisheries data (catch/effort) is available on an MPI database called CatchMapper. NIWA are usually contracted to quantify the trawl footprint. A report on FMA2 (~East Cape to Wellington – finfish and shellfish) also includes trawl footprint information. https://fs.fish.govt.nz/Page.aspx?pk=45&tk=389

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
31	**Commercial fishing financial loops**	Financial insight of members (FINZ)	M	FINZ may have some aggregate information on this as an industry, as well as multitude anecdotal data. It is noted that fisherman know (and may record) their own fuel consumption, not necessarily captured as a sector. Newer electronic motors with built in fuel consumption meters are not yet widespread. Hard to fully address revenue without considering: fuel cost; bottom contact; release of small fish. Other factors like tides influence fuel consumption as well
		Commercial catch records Fisheries NZ (MPI)	H	Commercial fishers must report their catch and position electronically. Records exist for 30+ years and can provide information on aggregate effort.
		Anecdotal data as proxy for understanding fishing loops (market records)	H	Historical records on price of fish from port (price per species per kilo), this is public information. Yet we do not have a detailed knowledge of this data. H level of data quality assumed. Ballpark quote price of fish.
		Estimates of the economic value of recreational fishing. (NZ Marine Research Foundation)	M	The New Zealand Marine Research Foundation investigated the economic value of recreational fishing, in terms of jobs and other economic activity. https://www.nzmrf.org.nz/files/New-Zealand-Fishing-Economic-Report.pdf
		Seafood economic and exporting information (Seafood NZ)	H	It is likely that there may be aggregate national scale data on the economic value of exported product. https://www.seafood.org.nz/
		Seafood consumer purchasing information (MPI)	L	Reports on what factors influence New Zealand consumers when purchasing seafood. including willingness to pay.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Gear modification studies (NIWA/FINZ)	M	Local fishers, Fisheries Inshore New Zealand (FINZ) and NIWA have collaborated on a number of innovative trawl gear trials in the Hawkes Bay region, to reduce the bycatch of juvenile fish and/or unwanted species and reduce benthic impact. These trials have included comparisons of different cod-end mesh configurations, maintaining the trawl doors above the seabed, and a completely new rigid meshed cage cod-end. The later project has been continued by NIWA within an MBIE funded Smart Idea developing an automatic fish identification and drafting gate system to exclude unwanted catch.
32	**Opportunities to collect kai**	Anecdotal data on fishing locations (Haggitt and Wade HB Marine Review)	L	The report contains anecdotal evidence on where people can and want to fish, and typical fish caught in these locations. Sites include deeper subtidal areas as well as beaches and estuaries.
		SOE data (HBRC)	M	HBRC sample popular shellfish gathering areas for compliance with microbial water quality standards. Could possibly be strengthened with input from Iwi knowledge.
		Anecdotal data (various Iwi)	L	Site access best determines opportunities to collect kai. As a proxy, determine the percentage of Māori land communities lost that front the coast.
		Anecdotal and empirical data Marine cultural health programme (Napier Port)	future	Project has two pou, Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be a model for expanding to other parts of Hawke's Bay.
33	**Pre-industrial level of seafood stocks**	Estimates of virgin biomass from all evaluated fish stock assessments. (MPI)	L	Estimates of virgin biomass for stock assessments, this informs the Maximum Sustainable Yield (MSY). Assumed Low as is always an estimate.
		Anecdotal and empirical data Marine cultural health programme (Napier Port)	future	Project has two pou (pillars), Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be model for expanding to other parts of Hawke's Bay.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
34	**Indigenous ecological knowledge and indigenous health loops**	Indigenous ecological knowledge (various Iwi)	H	Iwi have indigenous knowledge that may be able to support discussions around indigenous health and indigenous ecological knowledge. It is also noted that some tools that seek to quantify and articulate the health of these things better are currently under development (see also the Marine cultural health programme by Napier Port).
		Anecdotal and empirical data Marine cultural health programme (Napier Port)	future	**Sense of connection with Tangaroa** - Project has two pou, Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be model for expanding to other parts of Hawke's Bay.
		Anecdotal data (Ngati Kahungunu)	L	**Knowledge of identity (tikanga)** - Ngāti Kahungunu have information on community. Can compare members of the community that just know they are Kahungunu versus those that know where their marae is, have been to it, can recite their pepeha, etc.
		Anecdotal and empirical data Marine cultural health programme (Napier Port)	future	**Knowledge of identity (tikanga)/mana of kaitiaki** - Project has two pou, Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be model for expanding to other parts of Hawke's Bay.
		Pataka estimates (Takitimu seafoods)	H	Pataka kai has been given away for tangihanga for around 13 years. The data is high quality, at least for last 8 years. For each 10 kg box of fish the names of deceased, what region, town, marae / residence and amount. The only reason this data quality rating is not very high is is because more fish is provided through other means besides this accounting system.
		Cultural health indicators (DOC)	M	Report documenting Ngāti Kere's values, health indicators, and monitoring hopes for rohe moana regarding the Te Angiangi marine reserve

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
35	**Nutrition**	Public health records regarding food poisoning (DHBs)	H	Records relating to the number of instances of marine related food poisoning, such as paratyphoid.
		Public health records regarding population health (DHBs)	H	It is assumed that there are reasonable (population level) assessments of population health in general.
		Estimates of seafood proportion of diet (???)	unknown	Possible sources such as dissertations? Public health researchers? This was a possible suggested source, could be investigated in the future if considered useful.
		Anecdotal and empirical data Marine cultural health programme (Napier Port)	future	Project has two pou, Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be model for expanding to other parts of Hawke's Bay. Will contribute indirect information.
36	**Factors relating to fisher satisfaction, stress & mental health**	Anecdotal data on fisher satisfaction and mental health (Haggitt and Wade HB Marine Review)	L	The report contains anecdotal evidence of changes in ability to fish over time.
		Fisher mental health and welfare information (MPI)	L	Initiated last year to address mental health in fishing community, although no in Hawke's Bay. If MPI hears welfare complaints from fisherman, Guard Safety is brought in to address it.
37	**Public satisfaction with ecosystem health**	Resident surveys (HBRC)	L	Biennial survey to ascertain Hawke's Bay resident's attitudes towards the environment and awareness/satisfaction of HBRC's work. This would be a very loose proxy.
		Auckland Council Willingness to Pay survey (Auckland Council)	M	Auckland Council did a willingness to pay survey. Perhaps this could be used as anecdotal evidence, if it was assumed that it could transfer.

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Sustainable Seas values survey (Sustainable Seas)	L	A survey on how people value the ocean could provide anecdotal evidence here, but it is unlikely to transfer directly.
		Existence of HBMaC Group	L	The existence of the HBMaC Group can be viewed as evidence that Public Satisfaction is low and action is expected. Although this is only really anecdotal.
		Anecdotal and empirical data Marine cultural health programme (Napier Port)	future	Project has two pou, Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be model for expanding to other parts of Hawke's Bay. Will contribute indirect information.
		Public submissions on policy changes (HBRC)	??	Public submissions on policy changes could provide indication of public satisfaction with environment
38	**Advocacy factors (pro-new reg's & anti-new reg's)*** * This factor related to the changing levels (increasing or decreasing) of advocacy over time. Essentially that is what this factor seeks to demonstrate – advocacy as a response to what is happening.	History of advocacy from Iwi	H	Iwi have a long history of advocacy in relation to the marine area. This includes advocacy to Parliament resulting in statutes, various claims to The Waitangi Tribunal, treaty settlements in relation to the quota management system and fishing catch limits, etc.
		History of advocacy and desired regulations (Legasea)	M	The fact that Legasea exists is testament to the activity represented by this factor.
		History of advocacy from fishing interests (FINZ)	M	The fact that FINZ exists is also testament to the activity represented by this factor.
		Existence of advocacy groups (Hawke's Bay region)	L	• Forest and Bird (seabirds) • WWF (seabirds) • Greenpeace (trawling) • Ahuriri restoration group • Option4 (an advocacy group seeking to maintain rights of recreational fishers.)

No. on map	Factors on map	Knowledge type (and source)	Data qual. VH - VL	Comments
		Socio-economic impacts of local marine reserve (DOC)	M	Study on socio-economic impacts of Te Angiangi marine reserve
		Public submissions on policy changes (HBRC)	L	Analysis of public submissions on policy changes could provide indication of advocacy. Although this data exists in various places, collating and analysing it would likely require a significant effort.
39	**Community wellbeing**	Unknown	Unknown	Community wellbeing is referenced regularly (and has been historically), yet it is difficult to know what sort of data sets might be able to be used to support this. Potential sources may include empirical data from DHB (regional level data), MSD or StatsNZ. Qualitative and anecdotal knowledge may be sourced from Iwi and other community groups.
32, 34, 39, indrectly 35, 37	**Community wellbeing/health/connection with Tangaroa**	Anecdotal data Marine Cultural Health Programme (Napier Port)	future	Project has two pou, Health of moana and sense of connection with Tangaroa. It's based in Ahuriri/Napier for now, yet could be model for expanding to other parts of Hawke's Bay. Will contribute indirect information.

9. Summary

The report has summarised the first year of the EBM case study project in the Hawke's Bay, undertaken as part of the Sustainable Seas National Science Challenge. It has outlined a detailed description of a system map was developed for the dual stressors of freshwater sediments and loss of benthic structure due to seabed disturbance. This was done in conjunction with the HBMaC group, a non-statutory multi-stakeholder group convened by the Hawke's Bay Regional Council.

Following the detail description of the system map that was developed, this report has outlined potential ways that this system map can be used, including an 'analogue simulation' technique that will be used further in Phase 2 of this case study. Also, the project compiled a stocktake of known science-based, mātauranga, and community knowledge from a variety of sources that were assessed as being useful for informing the system map, and further enabling the implementation of EBM through scenario testing in Phase 2 of this case study.

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Appendix 1

Record of participants and attendees

ATTENDEE		WORKSHOP		
Name	**Affiliation**	**1**	**2**	**3**
HBMaC members				
Alicia McKinnon	Fisheries New Zealand	✓	✓	✓
Anna Madarasz-Smith	Hawke's Bay Regional Council	✓	✓	
Becky Shanahan	Hawke's Bay Regional Council	✓	✓	✓
Brianna King	Fisheries Inshore New Zealand	✓	✓	✓
Ngaio Tiuka	Ngati Kahungunu	✓	✓	
Paul Ratapu	Mahia Maori Committee	✓	✓	
Rick Birch	Napier Fishers Association	✓	✓	✓
Shade Smith	Ngati Kahungunu	✓	✓	✓
Te Kaha Hawaikirangi	Napier Port	✓	✓	✓
Wayne Bicknell	Legasea	✓	✓	✓
Sustainable Seas researchers or management				
Carolyn Lundquist	NIWA (Project Manager)	✓	✓	✓
Justin Connolly	Deliberate (Facilitator)	✓	✓	✓
Linda Faulkner	Sustainable Seas Management		✓	
Ian Tuck	NIWA (Fisheries Scientist)			✓
Julie Hall	Sustainable Seas Management			✓

Appendix 2
Glossary of factor names in the system map

This appendix contains a list of definitions for the factors named in the system map.

When reading the definitions of factors in the system map, most will be found to be of a higher-level of abstraction that they may usually be referred to, or they may even be highly subjective. This is intentional. The purpose of the system map is to provide a 'lens' through which to look at various different situations and/or geographic locations. Therefore, the factors have been worded in such a way that they can be used in various situations.

Some examples are noted below to demonstrate this:

- **excess erosion:** Erosion is a natural and ongoing process. Excess erosion is an articulation of a level of erosion that is in excess of what would be considered natural or should be considered acceptable in the current environment.
- **quality of land management practice:** This represents the societal expectations of the quality level at which land management practices should operate. Even though the general public are unlikely to know specifically what land management practices are (or should be), this node speaks to a level of public expectation derived from *community expectations of freshwater sediment amounts*.
- **all fisher satisfaction:** The sense of ***satisfaction*** that all fishers have in relation to the activity of fishing, whether this is undertaken for commercial, recreational or cultural purposes. Obvious this will be different for each case, but an aggregate is used here and can be considered in more detail when discussing the map.
- **sense of connection with Tangaroa:** The strength of the cultural connection that Māori feel with the ocean and the god (atua) of the ocean, sea and fish – Tangaroa. Tangaroa was one of the offspring of Rangi-nui and Papa-tū-ā-nuku.
- **'appropriate' level of benthic structure (yet to be agreed):** This factor described the upper level of a goal/gap relationship with the actual level of benthic structure. This describes an aspirational, desired or anticipated level of benthic structure. Importantly, it does not describe, prescribe or determine what that 'appropriate' level of benthic structure should be. It merely provides a placeholder in the structure of the system map to this. Any actual 'appropriate' level of benthic structure needs to be determined by a normative process separate to this map. Note – this factor was quite contentious with the group, primarily due to confusion amongst many that it predetermined what was an 'appropriate' level. It does not (hence 'yet to be agreed').

Factor name	Description
Left hand side	
excess erosion	Erosion is a natural and ongoing process. Excess erosion is an articulation of a level of erosion that is in excess of what would be considered natural or should be considered acceptable in the current environment.
sediment run-off	The amount of sediment that runs off from land into waterways.

Factor name	Description
soil productivity	The amount of productivity that is produced by soils. Or, a measure of the productive output from soils. This is not solely measured by any chemical composition of the soil (although this will be a contributing factor). This also recognises the growing role that the non-chemical composition of soils plays, as well as soil volume. See also *natural soil properties*.
natural soil properties	The volume of natural soil properties that are found in soils. This recognises the varying nature of soils across the region and a growing awareness/movement that soils are measured by more than just chemical composition. This may also include microbial content and soil volume.
absorptive capacity (water retention)	The capacity of soils to absorb and retain water. Water retention in soils plays an important role in the time that water takes to flow through the water cycle. Lower absorptive capacity leads to less water retention, resulting in water passing more rapidly from soils to waterways. Not only can this increase the level of water in waterways in peak events, it is also a contributing factor to the severity of erosion.
(nutrient) inputs	Human-applied nutrients to soil for the purpose of increasing the productive use of those soils for commercial purposes.
revenue	Revenue from landuse (whatever that might be).
cost	Costs of landuse (whatever that might be).
profit	Revenue from landuse minus the costs of landuse. The actual profit realised from landuse activity.
desired profit	That level of profit which is desired or sought by the person in charge of an enterprise. In this case relating to landuse.
profit 'DIFFERENCE'	This is a ***goal/gap equation***. It describes the difference between the *desired* level of profit and the *actual* level of profit. The *lower* this difference then the *closer* actual profit is to the desired profit. If this difference is *high*, then the actual profit is *further away* from the desired profit.
likelihood of investment in quality of land management practice	This describes the likelihood of investment in the quality of land management practices. This does not describe the actual investment in these practices, rather it speaks to the motivation and enabling of such investment. As a separate factor, it also acknowledges that there is a delay between the likelihood of this investment and the realisation of any investment. See also *quality of land management practice*.
quality of land management practice	This represents the actual level of a broad range of possible land management interventions, which in turn will vary across multiple different landuses. The use of *quality* in this node refers to both the qualitative and quantitative components of any such land management. For example, quality of land management practice might cover both the same amount of a land management practice executed in an improved way, as well as/or an increased application of a particular land management practice, regardless of the quality that it is applied.

Factor name	Description
expected quality of land management practice	This represents the societal expectations of the quality level at which land management practices should operate. Even though the general public are unlikely to know specifically what land management practices are (or should be), this node speaks to a level of public expectation derived from *community expectations of freshwater sediment amounts*.
quality of land management practice 'DIFFERENCE'	This is a ***goal/gap equation***. It describes the difference between the *desired* and *actual* levels the quality of land management practices. The *lower* this difference then the *closer* actual quality of land management practices will be to the desired quality. If this difference is *high*, then the actual quality is *further away* from the desired quality.
sediment traps	This factor relates to sediment traps or managed wetlands constructed on public lands or in waterways. This factor only applies to mechanisms where sediment is *removed from waterways*. This does not include sediment traps or managed wetlands that are constructed on private land, which *stop sediment from reaching waterways*. These are included in *quality of land management practice*.
new regulatory tools	This describes any new, or changes to existing, *regulatory* tools intended to influence land management practice. For example, regional plans.
new non-regulatory tools	This describes any new, or changes to existing, *non-regulatory* tools intended to influence land management practice. For example, volunteer subsidy schemes or extension work.
non-financial drivers of land management practice	This factor captures the non-financial drivers that motivate land owners/managers to maintain or improve the quality of land management practices. For example, a strong desire to ensure water quality or biodiversity.
community expectations of freshwater sediment amounts	This represents societal expectations of the amount of sediments that are acceptable in freshwater bodies. This is intended to represent more broadly the direction that sediment levels need to move. For example, significantly less, somewhat less, etc.
community expectations of freshwater sediment amounts 'DIFFERENCE'	This is a ***goal/gap equation***. It describes the difference between the *desired* and the *actual* amounts of sediments in freshwater. The *lower* this difference then the *closer* actual levels of sediments are to the desired. If this difference is *high*, then the actual levels of sediments is *further away* from the desired level – i.e. progress still has some way to go.
expectations for drainage/ movement of water away from assets	This represents societal expectations relating to the extent that water drainage and the movement of water away from assets is expected. This could also be articulated as the level of service expected of public and private water drainage assets.
channelised waterways	The amount of channelised waterways and 'hard' overland flow path assets in the wider societal stormwater network. This is independent of the owner of the asset.
potential streambank erosion	The potential for streambanks to be eroded due to the intensity of waterflow in streams.

Factor name	Description
frequency & intensity of weather events	The frequency and intensity of weather events. This is all events not just extreme events.
climate change	The scientifically recognised process of the global climate and weather patterns changing due to anthropogenic influences on the atmosphere, primarily due to the historic release of greenhouse gases.
middle	
Sediment in	The amount of sediment that physically *makes its way into* freshwater streams and rivers. This is considered the 'tap' or 'in flow' into the bathtub of sediment, from the bathtub analogy described in the report.
Freshwater sediments	This factor is one of the **focal factors** in the system map. The amount of *sediments suspended in freshwater* that physically make their way to the marine and estuarine environment in freshwater streams and rivers. Broadly, this is defined by the sediment load of these water bodies where they flow into the Hawke's Bay.
Sediment out	The amount of sediment that physically *settles out of* freshwater streams and rivers, after it has made its way in there. This is considered the 'drain' or 'out flow' from the bathtub of sediment, from the bathtub analogy described in the report.
marine suspended sediments	The amount of *sediments suspended in the ocean*.
turbidity	A measure of how optical properties of light that can pass through water, in other words, how much light is able to penetrate the water. High turbidity equates to low light penetration (darker), while low turbidity equates to high light penetration (lighter).
deposited sediments	The amount of sediment that physically *settles out of* the ocean and onto the sea floor, regardless of how it made its way in there.
water energy	The amount that water is moving as a measure of the energy contained within that water. This is the opposite of quiescence, which is a scientific term often used to describe the calmness of water. For example, water that is fast or regularly moving will have high water energy and low quiescence; water that is still will low water energy but high quiescence.
currents/ tides/ waves	The amount of currents, tides and wave action. In other word, the forces that create water energy. It is noted that his is a good example of where geographic specificity will be highly variable across the Hawke's Bay and it is not possible to be geographically specific within the system map. However, this is where the map may be used a 'lens' for one particular location and the power and influence of current, tides and waves at that location may be considered.
Benthic structure new	The create or (re)generation of any new benthic structure, whatever that may be. See also Benthic structure. This is considered the 'tap' or 'inflow' into the 'bathtub' of benthic structure, from the bathtub analogy described in the report.

Factor name	Description
Benthic structure	This factor is one of the **focal factors** in the system map. It was also deliberately described so as to have a wide range of application to various benthic settings. Here this describes the level and complexity of the 3D structure of or on the seabed. The term may be used to represent any type of benthic structure that may be the focus of discussion, at a certain geographical place in Hawke's Bay. Benthic structure covers a range of benthic types: it and could mean things that have no, or limited, 3D structure above the sediment surface such as soft sediments and gravel; or faunal or mineral structure such as reefs or rock structures; or even floral structures such as kelp beds. It is very important to note that the term 'benthic structure' applies to all of these and, in keeping with the intended use of this system map, specific cases may be kept in mind when discussing the dynamics of that system (with that specific type of benthic structure at its core) that the system map articulates. Importantly though, this factor represents the *actual amount* of any type of benthic structure being discussed. It does not represent whether that amount is considered appropriate or adequate in any way. This is important to retain the agnosticism of the system map. See also *'appropriate' level of benthic structure (yet to be agreed)*.
Benthic structure removed	The removal of benthic structure from the benthic environment, regardless of how this occurs. This is considered the 'tap' or 'flow' into the bathtub of sediment, from the bathtub analogy described in the report.
benthic structure 'DIFFERENCE'	This is a ***goal/gap equation***. It describes the difference between the '*appropriate'* (or *desired/target*) level of benthic structure and the *actual* level of benthic structure. The *lower* this difference then the *closer* actual level of the benthic structure is to the sought level. If this difference is *high*, then the actual level of the benthic structure is *further away* from the sought level. Note – this only describes this relationship in *quantitative* terms. It does not describe whether any desired/target/'appropriate' level is a good thing to have or not.
'appropriate' level of benthic structure (yet to be agreed)	This factor described the upper level of a goal/gap relationship with the actual level of benthic structure. This describes an aspirational, desired or anticipated level of benthic structure. Importantly, it does not describe, prescribe or determine what that 'appropriate' level of benthic structure should be. It merely provides a placeholder in the structure of the system map to this. Any actual 'appropriate' level of benthic structure needs to be determined by a normative process separate to this map. Note – this factor was quite contentious with the group, primarily due to confusion amongst many that it predetermined what was an 'appropriate' level. It does not (hence 'yet to be agreed').

Factor name	Description
appropriate organisms	Similar to 'appropriate' benthic structure above, this factor holds a place to account for the quantity and quality of a variety of organism associated with or supported by healthy benthic structure. Like benthic structure, this is deliberately abstract in order to account for a wide variety of types of organisms, as well as a variety of specific relationship between them and the benthic structure.
likelihood of crossing a recovery threshold	The likelihood of the benthic structure reducing to such an extent that it crosses a recovery threshold or 'tipping point', from which it may be extremely difficult or impossible to recover.
benthic recovery rate	The rate at which benthic structure recovers. Importantly, it is not intended or expected that this will be any kind of specific knowable rate, allocatable to different types of benthic structure. Rather, this is intended as a factor that provides an opportunity for an appreciation of recovery rate to be incorporated into the temporal discussion. This is likely always to be a relative and abstract, yet important, factor.
natural benthic recovery	Any process by which benthic structure itself recovers through natural processes that lead to its rejuvenation.
human benthic restoration action	Any process by which benthic structure is assisted in recovery by direct human intervention with the intention of rejuvenating the structure. For example, mussel bed seeding, reef seeding, etc.
change in average ocean temperature	The change in average ocean temperature over time.
change in average ocean pH	The change in average ocean pH over time.
bottom contact	The act of the seabed being disturbed through some kind of human contact or activity.
port dredging	The dredging of the port channel or other areas.
dredging spoil	The dumping of dredging spoil elsewhere in the ocean.
cable laying	The act of laying cables on the ocean floor for assorted purposes (telecommunications, power, pipelines etc).
shellfish dredging	The act of dredging the seabed for shellfish. Applies to both commercial and recreational use of this technique, although these will differ in scale.
Right hand side	
seafood stocks	This factor describes the quantity and quality of seafood stocks. As the system map takes an ecosystem view rather than a species view, no one species is specified. It is intended that this could relate to finfish as well as shellfish.
customary catch	Any seafood catch caught attributed under the customary catch allocation (one of three available) in the QMS.
recreational catch	Any seafood catch caught attributed under the recreational catch allocation (one of three available) in the QMS.
commercial catch	Any seafood catch caught attributed under the commercial catch allocation (one of three available) in the QMS.

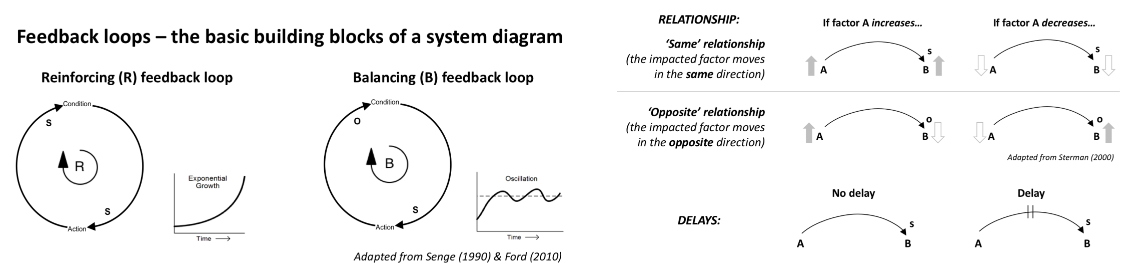
Factor name	Description
fishing restrictions	Any type of restriction that is imposed to restrict fishing. This could be regulatory or non-regulatory, as well as forced or voluntary (on the part of the fishers).
trawling quantity	The quantity of trawling occurring in Hawke's Bay. (For the quality of trawling practices, see trawling bottom contact)
trawling bottom contact	The extent that trawling practices make contact with the seabed, therefore describing their impact on the seabed. This is a proxy for the quality of trawling practices, at least in terms of bottom contact. (For the quantity of trawling practices, see trawling quantity)
fishing revenue	Revenue generated from commercial fishing.
species/size selectivity	This factor speaks to the practice of targeting specific species or sizes of fish for market. Note – this does not refer to high-grading or the dumping of smaller yet legal-sized fish in order to maximise the catch of larger legal-sized fish.
opex	Operating expenditure, as an input to the cost of commercial fishing.
capex	Capital expenditure, as an input to the cost of commercial fishing.
actual profit	Actual profit realised from commercial fishing. Revenue minus costs (capex & opex).
desired fishing profit	That level of profit which is desired or sought by fishers.
fishing profit 'DIFFERENCE'	This is a ***goal/gap equation***. It describes the difference between the *desired* level of fishing profit and the *actual* level of fishing profit. The *lower* this difference then the *closer* actual fishing profit is to the desired fishing profit. If this difference is *high*, then the actual fishing profit is *further away* from the desired fishing profit.
nutrition	The quality of nutrition of local communities. This factor is intended to apply to all community members. Most influencing factors will apply to all communities (e.g. *commercial catch*, *opportunities to collect kai locally*, etc), yet some may be more relevant (or only apply) to Māori communities (e.g. *pataka kai*).
opportunities to collect kai locally	The opportunities available to local communities to collect kai locally from the ocean. Primarily this refers to the ability to do this with a low level of technical entry. For example, being able to collect shellfish at the coast or to fish off the coast, without the need to access a boat or other expensive equipment. This speaks to both the opportunities available to do this as well as the likelihood that there will be kai available to collect.
pre-industrial level of seafood stocks	The level of seafood stocks that were present in the Hawke's Bay before the widespread operation of *industrial fishing* operations. Note – this does not refer to the *industrial revolution* (i.e. pre-colonial) times.

Factor name	Description
pre-industrial level of seafood stock 'DIFFERENCE'	This is a ***goal/gap equation***. In this case, the pre-industrial level of seafood stocks serves as a guide to how diminished the seafood stocks are, in relation to that historical marker. It describes the difference between the *pre-industrial* level of seafood stocks and the *current* level of seafood stocks. The *lower* this difference then the *closer* the *current* level of seafood stocks is to the *pre-industrial* level of seafood stocks. If this difference is *high*, then the *current* level of seafood stocks is *further away* from the *pre-industrial* level of seafood stocks.
pataka – compensation of manākitanga from commercial catch	This describes the situation that occurs where provision can be made to feed whanau from the commercial catch quota owned by Iwi. This is more likely to occur when customary or recreational catches are low.
mana of kaitiaki	The prestige, authority, status or respect (mana) accorded to those individuals within iwi/hapu that have a role as caretakers, guardians or stewards (kaitiaki) of the natural world.
knowledge and identity (tikanga)	The strength and appreciation of traditional knowledge and the resulting corresponding contribution that this makes to cultural identity. This is a strong contributor to traditional customs, procedures or protocols (tikanga).
sense of connection with Tangaroa	The strength of the cultural connection that Māori feel with the ocean and the god (atua) of the ocean, sea and fish – Tangaroa. Tangaroa was one of the offspring of Rangi-nui and Papa-tū-ā-nuku.
adequacy of community fishing management practices	Community fishing management practices covers all ways of managing fishing that are not part of legislation or regulation. For example, all voluntary or iwi/hapu led approaches. For example, this can also include the temporary retiring of quota rights in order to allow fish stocks to regenerate or taking lower-than-permitted catch bag allowances.
action to strengthen community fishing management practices	Action taken by communities, within communities, to establish or strengthen any voluntary or non-legislative fishing management practice, as described above.
perceived need for new regulation	The perceived need for new regulation to manage fish stocks of fishing practices. This is as perceived by any community. This factor may be an aggregate of the perceptions of various communities, or it could be used as a lens to view the perceptions of one particular community (or subset).
pro-new regulation advocacy	Advocacy ***for*** *an increase* in regulation to manage fish stocks or fishing practices.
anti-new regulation advocacy	Advocacy ***against*** *an increase* in regulation to manage fish stocks or fishing practices.
government regulation	The level and quality of government regulation and legislation, with regards to managing fish stocks and regulating fishing practices.
commercial fisher job security	The likely security of the jobs of commercial fisherman.

Factor name	Description
all fisher satisfaction	The sense of ***satisfaction*** that all fishers have in relation to the activity of fishing, whether this is undertaken for commercial, recreational or cultural purposes. Obvious this will be different for each case, but an aggregate is used here and can be considered in more detail when discussing the map.
all fisher stress	The sense of ***stress*** that all fishers have in relation to the activity of fishing, whether this is undertaken for commercial, recreational or cultural purposes. Obvious this will be different for each case, but an aggregate is used here and can be considered in more detail when discussing the map.
all fisher mental health	The sense of ***mental health*** that all fishers have in relation to the activity of fishing, whether this is undertaken for commercial, recreational or cultural purposes. Obvious this will be different for each case, but an aggregate is used here and can be considered in more detail when discussing the map.
all fisher sense of stewardship	The sense of ***stewardship that all fishers may feel*** in relation to how well they feel they are caring for the fishery, through their activity of fishing, whether this is undertaken for commercial, recreational or cultural purposes. Obvious this will be different for each case, but an aggregate is used here and can be considered in more detail when discussing the map.
wider community sense of stewardship	The sense of ***stewardship that the wider community may feel*** in relation to how well they feel that the society of which they are a part is caring for the fishery. This is even though as individuals they are not directly involved (even culturally or recreationally).
all fishers feel part of community	The extent that all fishers feel that they are a welcome and valued part of the wider community.
public satisfaction with ecosystem health	The extent that the wider community and public and satisfied with the quality of the ecosystem health in the Hawke's Bay. This specifically includes those members of the public who are not directly engaged with fishing or even the ocean. They form an opinion based on the perceptions they have from their personal experience of the ocean (if any). They also form opinion based on the perceptions of courses around them, such as personal connections, media, government information etc.

Appendix 3

Full detailed copy of the system map



HBMaC system map Phase 1 of EBM case study 2020.