Report for the Sustainable Seas National Science Challenge

Piloting the use of Systems Mapping in the Sustainable Seas National Science Challenge.

January 2019

Report by:

Justin Connolly Director, Deliberate

Author

Justin Connolly

Director, Deliberate

January 2019

Acknowledgements

Funding for this work was provided by the Sustainable Seas National Science Challenge.

The author gratefully acknowledges the opportunity to pilot a systems' mapping approach with the Sustainable Seas National Science Challenge. Also, thanks to the participants who freely gave their time over the course of an intense month of workshops and meetings. Without their involvement there would have been no pilot.

Version

Date	Comments	Authorised by
31 January 2019	Peer-reviewed report issued to client for comment.	Justin Connolly Director, Deliberate
04 March 2019	Finalised report issued after client comments incorporated.	Justin Connolly Director, Deliberate
10 August 2020	Report cover updated with Sustainable Seas logo and updated attribution of funding.	Justin Connolly Director, Deliberate

Table of contents

1 Introduction 1
2 Process overview 2
2.1 The focus issue – the decline of scallops 2
2.2 The three-workshop process 2
2.3 Participants 4
2.4 Collection of survey data 5
3 Observations of the process 5
3.1 Workshop 1 5
3.2 Interviews between workshops 1 & 2 7
3.3 Workshop 2 8
3.4 Interviews between workshops 2 & 3 9
3.5 Workshop 3 10
4 Summary of survey data from participants 19
4.1 Survey to assess possible mental model change 19
4.2 Survey feedback from participants about the process 23
5 Summary and recommendations for moving forward 31
6 References 34
Appendix 1 Using the decline of scallops as a trend to focus the conversations 35
Appendix 2 Draft system map developed in this pilot 36
Appendix 3 Pre-test/post-test survey to test mental model change 53
Appendix 4 Post-pilot survey about participants experience of the workshops 54
Appendix 5 Copy of previous report 57

Table of figures

Figure 1. Stylised trend line (behaviour of time) of scallop decline in Tasman/Golden Bays, as used in the workshops. 2

Figure 2. Diagram showing the three workshops in the pilot.... 3

Figure 3. Screen shot of factors suggested in first workshop.... 7

Figure 4. Feedback loops – the basic building blocks of system maps.... 8

Figure 5. Draft system map after refinement in Workshop 2.... 11

Figure 6. Interventions suggested in Workshop 3 after developing the draft system map 12

Figure 7. Anticipated behaviour over time of selected variables if wetlands were restored or constructed. 15

Figure 8. Anticipated behaviour over time of selected variables if 3D structure was constructed on the seabed.... 16

Figure 9. Anticipated behaviour over time of selected variables if all bottom contact fishing methods (dredging and trawling) were banned. 17

Figure 10. Number of variables listed by respondents before the workshops compared with after the workshops. 21

Figure 11. Quantitative survey results of participants experience of the process – graphed 26

Table of tables

Table 1. Content analysis of pre/post-test surveys to determine if mental model change had occurred 20

Table 2. Content themes of the variables, listed by respondent. 21

Table 3. Quantitative survey results of participants experience of the process – tabulated 25

Table 4. Qualitative feedback that was supplementary to quantitative questions.... 27

Table 5. Qualitative feedback that was in response to open ended questions 29

1 Introduction

In late 2018 Justin Connolly from Deliberate was commissioned to run a pilot 'systems mapping' process for the CP2.1 project of the 'Sustainable Seas' National Science Challenge. The purpose of this trial was to explore whether systems mapping, an approach based on Systems Thinking (or more specifically the qualitative tools from the discipline of System Dynamics) may be useful in Ecosystem Based Management (EBM). If so, its further application may be incorporated into the second tranche of the National Science Challenge, due to begin in July 2019.

EBM is defined as a holistic and inclusive way to manage marine environments and the competing uses for, and demands on, the ways New Zealanders value them. Sustainable Seas is researching how the possible application of EBM may be approached. The practical issue that much of the Sustainable Seas EBM case study workshops had been anchored around is the declining (or declined) sea bed health in the Tasman Bay and Golden Bay (TBGB) area. To be sympathetic to that aim, the issue that was focused on in this pilot was the decline in scallops in the TBGB area, where the fishery is currently closed.

The concept of Systems Thinking is explained in a previous report by Deliberate that outlined its theoretical underpinnings and proposed the approach for this pilot. For further detail the reader is referred to that report – *Conceptual options for incorporating Systems Thinking into Project CP2.1 of the Sustainable Seas National Science Challenge* (see Appendix 5).

This report summarises a three-workshop process that was undertaken in the pilot. That process resulted in a draft system map which helped participants gain insights into the influences that affected scallops. While this map is described in this report and considered a useful starting point for the work of the Science Challenge, it is only considered draft as the selection of participants was limited in the pilot, compared to a more comprehensive process. This report focuses on the pilot process: what worked well and what did not, and what could be learned if the process was to be applied in tranche two of the Challenge with a wider range of stakeholders and applied to an actual to be made. Several things inform the insights in this report: the observations of the facilitator and supporting staff; information provided by participants in feedback forms; and general conversation between the participants and the facilitator/staff.

Section 2 of this report provides an overview of the system mapping process. Section 3 presents observations of the process from the perspective of the facilitator, informed by conversations with participants and supporting researchers. Section 4 summarises data collected from participants via two surveys – one assessing the impact of the system mapping process on their mental models, the second evaluating their experience of the process. Section 5 provides a summary and outlines some recommendations for possible future applications of this process.

2 Process overview

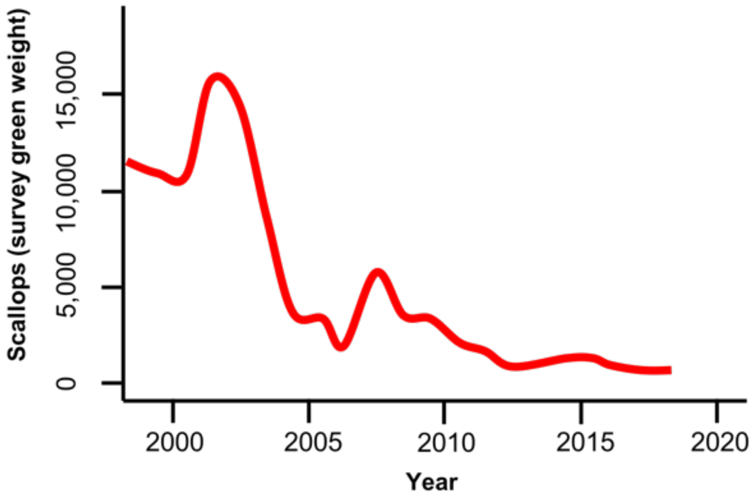
This section outlines the three-workshop process and the profile of participants in the pilot.

2.1 The focus issue – the decline of scallops

In preparation for the workshop the issue of scallop decline was determined to be a useful subject to focus this pilot on. Scallops were chosen for several reasons: they were being studied in other parts of the challenge, so it was synergistic with this other work; and because scallops' habitat is the seabed, it was considered that focusing on scallops would provide much of the same insight as a focus on the seabed itself, which was also of interest to the challenge.

The stylised trend line of scallops decline that was used to focus the workshop conversations is shown in Figure 1. This stylised line was drawn of actual data points from graphs in *Survey of scallops in SCA 7, January 2017: New Zealand Fisheries Assessment Report 2017/23* (Ministry for Primary Industries, 2017). More detail as to how this was determined is outlined in Appendix 1.

Figure 1. ***Stylised trend line (behaviour of time) of scallop decline in Tasman/Golden Bays, as used in the workshops.***



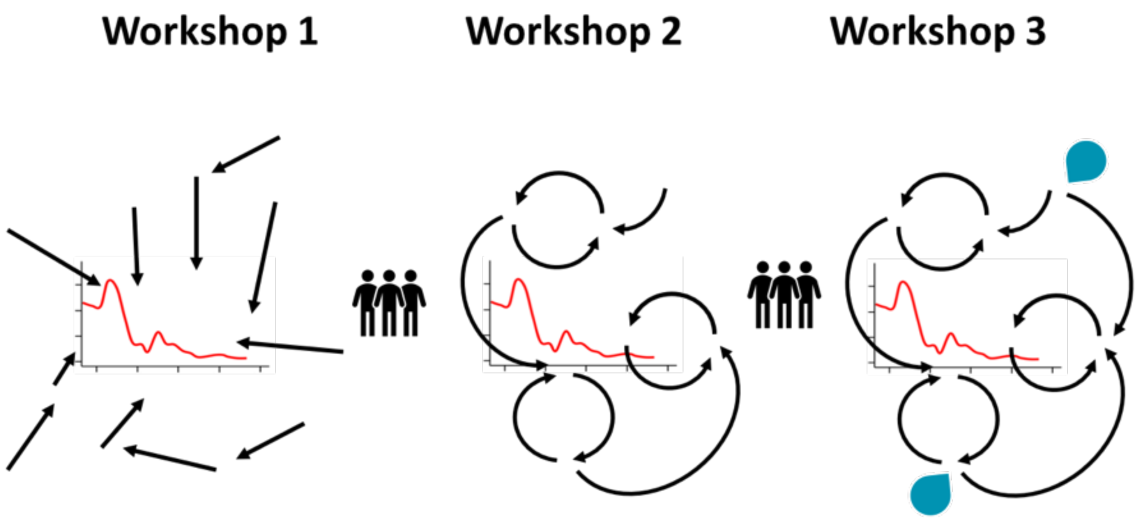
2.2 The three-workshop process

The pilot process was made up of three workshops that began at 3:30pm and ran until approx. 8:00pm. A break for dinner meant that this was around 3.5 to 4 hours of productive time. Normally such workshops would be run over a whole day, meaning greater productive time. However, it was agreed that to limit resources and the input of the participants involved, this would be run as a pilot – an abbreviated version of a more comprehensive process. As a result, the ability to fully explain and explore some concepts were limited (more on this in Section 3). The intention was always that this was designed as a way of testing the process to see if it was likely to be useful in tranche two, rather than running the process through to a comprehensive completion.

The observations in this report should be read with this shortened version of a comprehensive process, in mind. A comprehensive process would accommodate more time as well as a wider range of participants (more on this in the next section).

A conceptual diagram showing the three workshops is shown in Figure 2 below. The three images of a line graph and arrows represent each workshop; the groups of people between each workshop represent the follow-up one-on-one interviews with participants between the workshops.

Figure 2. Diagram showing the three workshops in the pilot



The process was as follows:

- **Before the workshop** the issue that the workshops would be 'anchored' around was determined (scallop decline). Figure 2, above, indicates the centrality of this trend as the focus of the three workshops.
- **Workshop 1** introduced participants to the concept of systems mapping and elicited initial factors that they believed influenced the decline in scallops. This is stylised in Figure 2 with the scallop trend graph and various disparate arrows pointing in many directions.
- **In between Workshop 1 & 2** participants were interviewed individually, and the factors elicited by the group were explored in more detail. The facilitator then began building some of the main feedback loops that were operating in the map. (represented by the people in Figure 2)
- **Workshop 2** presented the initial draft system map back to participants and further refinements to the factors and influence arrows were made. This is represented by the stylised map for Workshop 2 (in Figure 2) containing more loops and having more structure.
- **In between Workshop 2 & 3**, participants were again interviewed individually. This allowed the facilitator to again refine the structure of the system map for use in Workshop 3. (again, represented by the people in Figure 2)
- **Workshop 2** presented the refined map back to participants again (briefly). This workshop focused on identifying/discussing possible interventions that the system mapping highlighted. Qualitative graphs of the behaviour of variables over time were

generated to support this discussion. The intervention points are represented by the blue points on the stylised system map in Figure 2.

The three workshops were run over a four-week period in November-December 2018. The workshop dates were: Workshop 1 on Monday 12th November; Workshop 2 on Tuesday 20th November; and Workshop 3 on Tuesday 4th December.

The proximity of the workshops to each other was requested by the facilitator. Previous research (Connolly, 2017) has found that because the systems mapping approach is a novel approach for most participants, having workshops close together ensures momentum carries through the workshops. Too long a time between workshops may mean participants begin to forget the context of discussions that were had previously. However, this comes with an associated burden or time and resources.

These workshops are qualitative and rely on the knowledge of participants to describe the system they collectively seek to understand. While certain areas of specificity could be expanded on through intervening participant interviews, additional literature reviews or reading or research was not requested of participants between each workshop. This enables them to be scheduled relatively close together and for momentum to be built and maintained.

2.3 Participants

Participants were determined by the project manager, Judi Hewitt, after discussion with the project team. A maximum limit of 12 was requested by the facilitator, as this is considered a maximum manageable number for groups *per systems facilitator* within systems mapping workshops (Connolly, 2017, Vennix, 1996).[1]

Participants were selected based on either their institutional knowledge (i.e. they were from a Council, Government agency, or research institute) or their ability to provide a Māori perspective. Māori participants were invited to provide a general Māori perspective, rather than a specific Iwi perspective.

Workshops began at 3:30pm and ran into the evening. This was intended to suit both people who could attend as part of their jobs, as well as people who had to attend in their own time.

Nine participants attended the first workshop. Five were from natural resource management institutions (councils or government agencies), three provided a Māori perspective, and one provided a specialist research perspective (with scallops as their subject matter). One participant from a government agency attended via Skype for the first and last workshop, and in person for the second workshop. One of the Māori participants was only able to make the first workshop, and neither of the subsequent workshops. One participant from a resource management institution could not make the final workshop.

[1] This does not mean that workshops may *only* include 12 participants. Workshops can, of course, contain more participants than this but they require additional logistical requirements. Primarily the need for additional experienced system mapping facilitators, in order to work with smaller groups within a larger workshop, up to a maximum of 12 people per sub-group.

2.4 Collection of survey data

Two survey processes were used to collect data for analysis.

A pre-test/post-test survey of participants was run before the initial workshop and after the final workshop, to determine the factors that participants perceived to be contributing to scallop decline. This provides *ex-ante* and *ex-post* insight to participants' understandings about key processes influencing scallops, and importantly, how that understanding may have changed during the workshop process.

A second survey of participants was undertaken after the final workshop, to elicit perspectives on participants *experience of* the process. These insights may help refine the process in any future applications, within this Science Challenge or elsewhere.

3 Observations of the process

The previous section provided an overview of the pilot process. This section provides observations about the pilot from the workshop facilitator's perspective, informed by his own observations as well as conversations with supporting researchers. While this is subjective data and the obvious bias of the facilitator is noted, every effort has been to ensure objectivity in this report, including a peer review by other supporting researchers. Notwithstanding, this perspective is valuable because the facilitator is an experienced systems facilitator and has has undertaken other research into participatory systems mapping processes (Connolly, 2017).

A summary and discussion of the survey data gathered from participants both before and after the workshops is found in section 4.1.

3.1 Workshop 1

The first workshop in a series is always important. It is an opportunity to introduce the facilitator, the participants to each other, and most importantly, the subject of the workshop. As these workshops were compressed into around half the time of a normal systems dynamics process, some (important?) things had to be removed.

This workshop attempted to make most efficient use of time available by beginning with an exercise that asked people to brainstorm the three most important factors that they believed were contributing to a decline in scallops. Importantly, participants were asked to name factors in a way that could be described as increasing or decreasing; improving or declining, as this is a core component of system mapping (Sterman, 2000). For example, a factor such as '*good* scallop health' should be avoided as this is a *qualified* description – if it was to decline it would be described a 'decline in good scallop health', which makes understanding difficult. Rather, this factor should be described simply as 'scallop health', which various influences may either increase (leading to 'good' or 'improved' scallop health) or decrease (leading to 'bad' or 'declined' scallop health).

These factors were then collated through a group sticky-board exercise, and similar factors were grouped and renamed as appropriate. Connections between these factors were then explored on a whiteboard that was projected onto the screen, via a document camera. This was done in the System Dynamics style of using arrows annotated with either an 'S' for Same or "O" for Opposite influence (Sterman, 2000). A same influence means that the influencing factor moves in the *same direction* as the influenced factor (i.e. both up or both down); an opposite influence means that the influencing factor moves in the *opposite direction* as the influenced factor (i.e. if one goes up the other goes down, or vice versa).

In general, participants found the first workshop confusing and frustrating, especially in the early stages when people were contributing factors. This is perceived to be due a range of factors, described below in no particular order.

Firstly, little context was provided for how this pilot fitted in with the wider Science Challenge. The systems mapping facilitator was not involved in the wider Science Challenge and so could not provide this. The comments of some participants suggested that a heavy burden of participation in various components of the Science Challenge to date was taking its toll. This was often at significant personal cost (in terms of time and commitment) and there seemed to be some fatigue from all the involvement. In effect this meant that there was some resistance and caution to what was perceived to be a new and mal-coordinated piece of research.

Secondly, the constrained time available had an impact on the success of the workshop. Because there was little time to provide a more comprehensive introduction, a 'diving straight in' approach was used to generating factors and discussing influences. This limited the opportunity to run through a more comprehensive introductory exercise to familiarize participants to each other and with the concept and purpose of systems mapping.

Systems mapping is usually a novel approach to most participants. It is often best to provide some context at the beginning but not to explain all details of systems mapping, rather to expand on that as the workshops progress. A comprehensive description of the systems mapping approach through to completion and results could easily have taken half of the time available for the first workshop, which was not considered a practical use of time. Usually a partial introduction and a 'learning as we go' approach has been found to be the most useful (Connolly, 2017). However, in this instance, and perhaps due to the mediating factor of a lack of context already discussed, more of a description of the journey that the three workshops would take would have been useful.

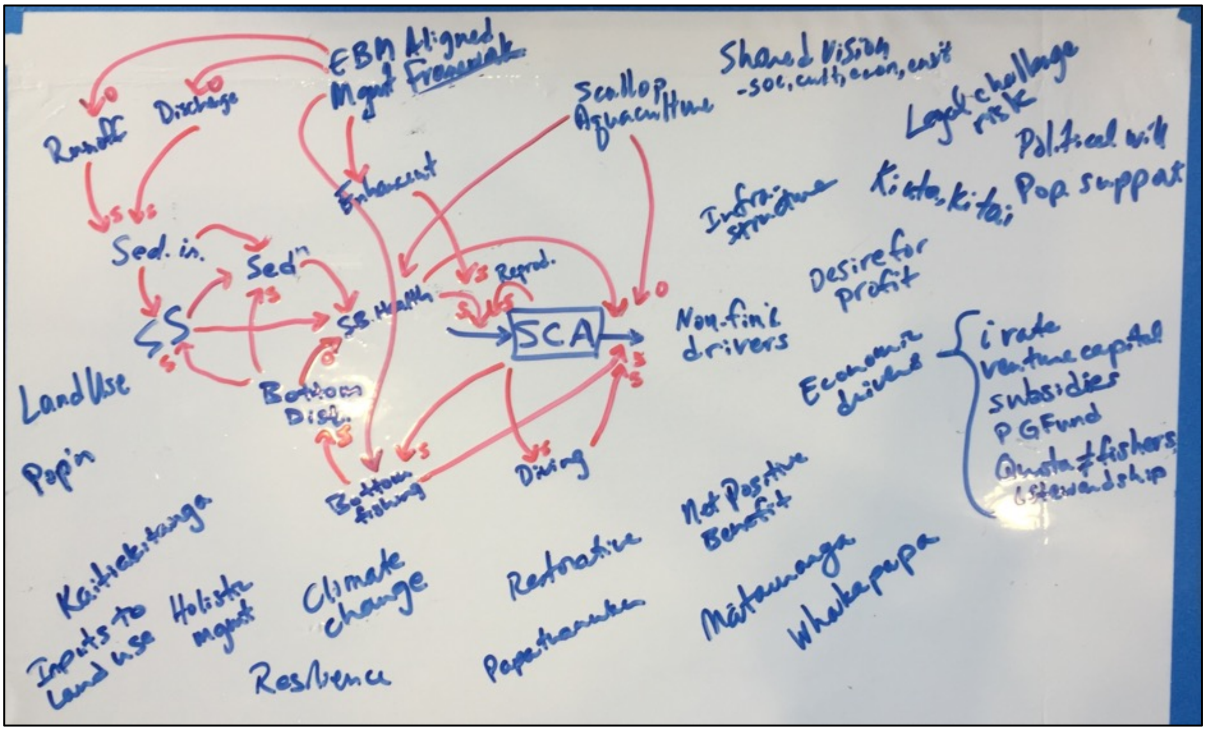
Thirdly, there was some discomfort amongst Māori participants as to how a Māori perspective might be provided and incorporated into this approach. The two factors discussed above may have also compounded this frustration. While many Māori terms and concepts were contributed when generating factors, attempts by the facilitator to explore or frame these in such a way that they could increase or decrease, there was significant discomfort from Māori participants.

It was felt that this frustration could and should have been better anticipated when planning for the pilot and there were doubts as to whether the systems mapping approach could incorporate Māori concepts like whakapapa and whanaungatanga, which underpin a Māori perspective of the inter-relationships and connections between factors. A separate Māori workshop to explore a Māori perspective on the decline of scallops was suggested and it was agreed this would be explored.

Two Māori participants were not able to join the workshop until approximately 5pm, so unfortunately this meant that they missed the brief introduction.

These frustrations acknowledged, the workshop evolved as the session progressed. Rather than pursuing the original approach of attempting to draw connections between influences, it was adapted and the latter part of the workshop focused on participants sharing and discussing possible factors that influenced scallops (Figure 3). These would later be explored more thoroughly in the follow-up interviews.

Figure 3. ***Screen shot of factors suggested in first workshop***



Even though this first workshop was frustrating for many of the participants, many of the factors suggested by participants were very useful from a system mapping point of view. The important element of this was the varied *types* of factors that were contributed. While there were obvious bio-physical factors, there were also many socio-cultural concepts. Therefore, an important outcome was achieved which was the sharing of a wide range of various factors. This offered participants insight into how other participants viewed the system that had resulted in a decline in scallops.

3.2 Interviews between workshops 1 & 2

Eight of the nine participants were available for a follow-up interview in the week following Workshop 1, in the lead-up to Workshop 2. The intention of these interviews was to further explore some of the factors that participants thought were contributing to the decline in scallops, in order to help build up the structure of the system map.

After Workshop 1, the first part of most of these interviews was spent reflecting on the process of the first workshop (and how it may have been run differently), discussing the perspective that the particular participant brought, and explaining the concept of system mapping. This was very useful and highlighted that this is a necessary component of the introduction to the first workshop and should be retained, even if abbreviated.

The second part of the interview focussed more on discussing various factors and influences that each participant was more familiar with. This enabled various components of the system map to be explored in more detail. Some perspectives were higher-level while others were quite detailed, another dynamic of the system mapping process which needs to be navigated.

The components discussed to date were collated into an initial system map for discussion in Workshop 2. Where possible this was represented on the one system diagram, with some small components represented separately until they could be discussed and included in the wider system map.

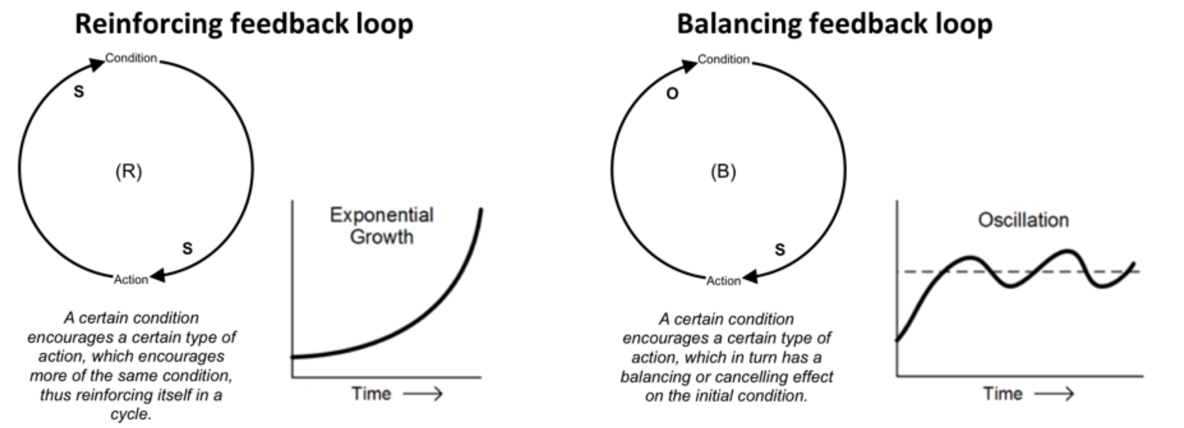
3.3 Workshop 2

Eight participants were available for Workshop 2. It began with one of the project sponsors (a senior manager from the organisation that physically hosted the workshops) reintroducing this pilot in the context of the wider Science Challenge. Assurances were given that any system map generated would be of use to the wider Science Challenge – whether the pilot resulted in further application of the system mapping approach or not. It was also noted that as participation for this pilot was limited, any information that was provided to the wider Science Challenge would be qualified as being from a pilot, and noted as not being developed with comprehensive involvement of all stakeholders.

The intended arc of the three workshops was also reintroduced. Workshop 1 was to gather initial factors and influences; Workshop 2 would present those in an initial system map and refine it further; and Workshop 3 would finalise a draft system map and consider possible interventions and their impact (based on the system map).

Further, the important systems thinking concepts of feedback loops and the direction of influences ('same' and 'opposite') were also outlined at the start of this workshop (Figure 4).

Figure 4. Feedback loops – the basic building blocks of system maps



Adapted from Senge (2006) and Ford (2010)

As a result of the interviews that had occurred and the reintroduction of these concepts, there seemed to be a greater level of comfort with the flow of the workshop.

The balance of this workshop then focused on the draft system map and the factors and loops that had been identified. Discussion focussed on the definition of the factors, in general making factors more detailed or specific, which in turn resulted in the identification of more factors. As with all system mapping exercises, the facilitator was constantly asking the group "what is the simplest way of representing the factors without being too complex?" From the facilitators experience the detail versus aggregation debate is a constant and very important element of system mapping (Connolly, 2017; Vennix, 1996).

This workshop felt more productive than the first one and resulted in greater system mapping progress. Many participants described insights to the dynamics of a systems behaviour over time, which led to an articulation of structure, while others learned from these descriptions. Many of the factors and influences already described were further discussed and better understood.

What came out of this workshop was a more comprehensive visual articulation (in the map) of the many factors influencing scallops. One of the important insights was that an influencing factors proximity (defined by number of connections) to scallops did not necessarily make it more impactful. These were often themselves influenced by (or influenced) other factors many connections further away from the scallops (such as productive land use, urban growth, or desire for non-commercial catch). See Appendix 2 for an overview of the map and factors. Many of these more distant factors tended to be at a higher level of aggregation, such as desired financial return or sustainable market drivers. Having significantly different levels of aggregation within one map may or may not be a challenge if this map was further developed. Indeed further develop would provide the opportunity to align the aggregation as much as possible. Nonetheless, the inter-connections that were beginning to be elicited appeared insightful for most participants.

At the end of Workshop 2 several participants commented that while they were quite mentally drained, they were enjoying the discussion and the workshops. They were tired but visibly engaged, which is consistent with the facilitator's previous experiences of system mapping (Connolly, 2017). Most participants appeared to be learning from each other, even when scallop ecology was their existing area of expertise.

3.4 Interviews between workshops 2 & 3

The second round of follow-up interviews focused on further refining the factors and influences that had been identified to date. Some discussion was also focused on the fact that many of the distant factors provided a consistent driver or pressure on other parts of the system, yet they were considered too large or dominant to alter.

For example, an important driver was the desire for financial return from investment. This influences many things not represented in this map, other than just the factors that influence scallops (predominantly fishing and land use), yet it highlighted that many of the interventions that may be made would continue to have this pressure on them. Therefore, this may impact the effectiveness of that intervention over time.

These conversations suggested that the systems mapping process helped participants identify where the best leverage could be gained for making some kind of change in a system.

3.5 Workshop 3

The final workshop was made up of two parts. First, the revised draft system map was presented back to the group. Second, some potential interventions were identified, based on the system map that had been developed. These interventions were discussed and their impacts over time on several key variables were qualitatively sketched out.

As it was the culmination of the three-workshop pilot, Workshop 3 is discussed in more detail here.

3.5.1 Finalising the system map

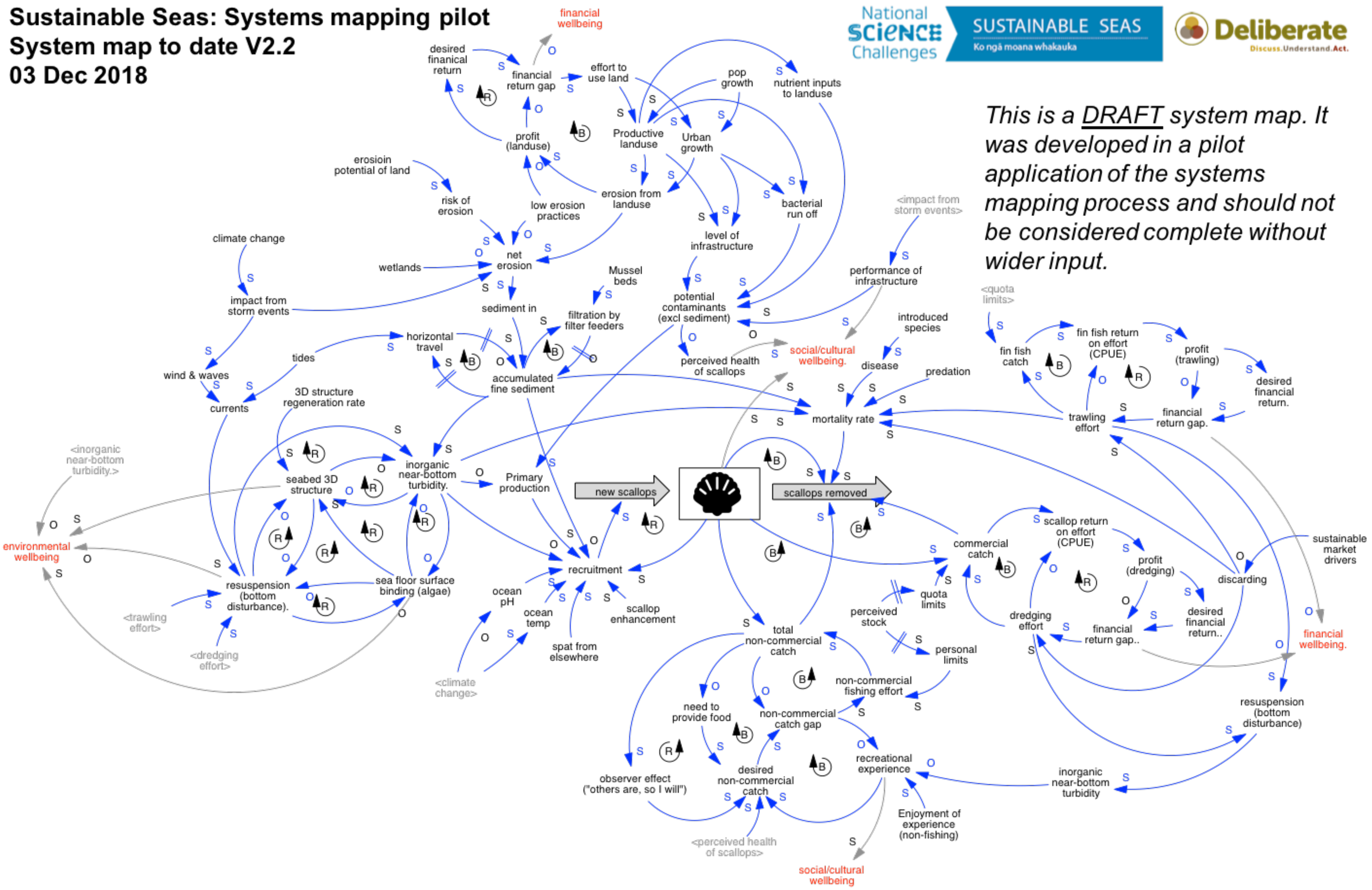
Presentation of refinements that had been made to the systems map was intended to constitute only a brief part of this workshop. However, it ended up taking approximately half of the workshop, as some participants had slightly differing understandings of some of the variables in the map (see also footnote 2). Which were then discussed. It also demonstrated (like any modelling process) that no system map would ever be 'perfect' and that a point would always be reached where a decision would have to be made to stop developing the map. The draft system map presented in Workshop 3 is shown in Figure 5.

As this was a condensed system mapping process, the amount of time allocated to it in this instance was not deemed sufficient to enable a robust refinement or 'completion' of the map to a point where all participants would endorse it. If the process was used further in the future, adequate amounts of time need to be allocated to ensure this is possible.

The confusion expressed by some participants about some of the variables highlights the importance of clearly defining factors and keeping a list of definitions. For example, there was some confusion as to what constituted a 'scallop' and thus a progression from the 'recruitment' arrow to the box that represented scallops. Was this when a scallop 'dropped' to the seabed? Was it when it was old enough to reproduce? Was it when it became of harvestable size? This may not have been clear when first described, or it may have become confused over the course of the workshops.

Suggestions for further refinement of the map were noted, though it was acknowledged that these refinements could not be made within the condensed workshop process.

Figure 5. Draft system map after refinement in Workshop 2



3.5.2 Identifying interventions

A card-storming exercise identified a range of potential interventions. These suggestions were then collated.

Figure 6. Interventions suggested in Workshop 3 after developing the draft system map

Possible intervention	Description
Increasing 3-D structure of seabed	Any or all of: shell hash; live shells; implant man-made structures.
Reduce bottom contact	Any or all of: decrease dredging; decrease trawling; close some areas completely to both trawling and dredging.
Reduce land riverbank disturbance	Any or all of: reduce or control disturbance; restrict land use; improve river management to avoid erosion; control activity on land.
Restore wetlands	Any or all of: Plant riparian areas and (re)establish wetlands; (re)establish wetlands in estuarine areas; target 'hotspots' where greater sediment/nutrient loss occurs.
Encourage product value-add	Any or all of: increase access to markets that pay a premium for sustainable products; increase the amount of value-add product produced locally; incentivise fishers to minimise bottom contact.
Reduce take	Any or all of: reduce the scallop harvest (commercial and non-commercial); amend the Total Allowable Catch (TAC).
Education	Any or all of: increase education about the issues of seabed health and scallop decline; seek to influence the public perception about these issues, so that there is public support for alternative management; Undertake targeted forestry education so as to reduce sedimentation.
Increase mussel farms	Increase coverage of mussel farms
Increase biosecurity management	Increase biosecurity management practices so that there is a lower risk of biosecurity incursions

Possible intervention	Description
Increase scallop enhancement	Increase scallop enhancement activity – providing places for spat to gather/develop and/or seeding seafloor with juveniles
Improve technology used in harvesting	Any of all of: promote sustainable fishing technology; change the management system to manage for technology, not just species.

Several interventions were chosen to discuss and qualitatively graph (by hand) the change that each intervention might prompt in other factors over time (all other things being equal). Three different types of interventions were discussed:

- Restoring wetlands,
- Increasing 3D structure of seabed, and
- Eliminating bottom contact.

At this point it is worth expanding slightly on the role of system mapping in the discipline of System Dynamics. While system mapping is the term used in this pilot, the formal name for the types of diagrams drawn in these workshops are *causal loop diagrams (CLD)* or *stock and flow diagrams (SFD)*, depending on their exact components and complexity. These tools exist at the qualitative end of the spectrum of System Dynamics tools. They are often the first step towards developing more formal simulation models, based on parameterised stock and flow modelling.

This is mentioned for two reasons. Firstly, it is important to know that while 'system maps' are useful qualitative tools by themselves, it may be possible to expand them to more complex and robust system *simulation* models. While that is not what they are being used for here, the application of System Dynamics maps are not limited to qualitative system maps.

The second reason this is important is because the qualitative graphing undertaken in the third workshop, is an approach sometimes used in System Dynamics to test whether the structure of the system map is likely to explain the behaviour. This step is often undertaken as part of progressing to a simulation model.

The qualitative graphing used in this system mapping pilot was seen as a pragmatic way of testing the dynamic hypothesis (structure) of the system map developed, without needing to develop more complex simulation modelling. Also, this approach may identify factors and influences that should be included in other modelling being undertaken on the Science Challenge.

3.5.3 A qualitative discussion of the perceived dynamic behaviour of interventions

Having identified several interventions to explore (wetlands, 3D structure and eliminating bottom contact), each intervention was taken in turn and its relative impacts discussed. Two A1 printouts of the system map were provided for participants to sit around, and a hand-drawn graph of behaviour over time for the key variables was projected onto the screen.

The process for this was simple. Firstly, X and Y graph axes were drawn. The X axis represented time and an arbitrary set of time stamps were added to this to keep it consistent across all examples. These were: the present (where the X and Y axes intersect); short term (5 years); medium term (20 years); and long term (50 years). The vertical axis represented a change in the variable and remained without a scale as it was a simple relativity exercise. Then key variables were identified and labelled; the behaviour over time of the intervention being discussed was sketched; and the corresponding impacts on the other variables (and any change in them on each other) were sketched. The result was a highly qualitative but insightful representation of the anticipated behaviour over time of key variables within the system, in response to an intervention.

Each intervention was discussed at a local level only and it was not determined what scale they may apply, for example the entire bay or a small section of it. It was not necessary at this point as it was a hypothetical exercise designed to see if this tool has application in future tranches of the Science Challenge.

Each intervention was also considered in isolation. While in reality a variety of interventions might be undertaken, for simplicity only one was considered at a time here. In addition, all other factors (such as land use etc) were considered as remaining constant. While these influences would vary in reality, these constant assumptions were made simply to demonstrate and test the utility of this approach.

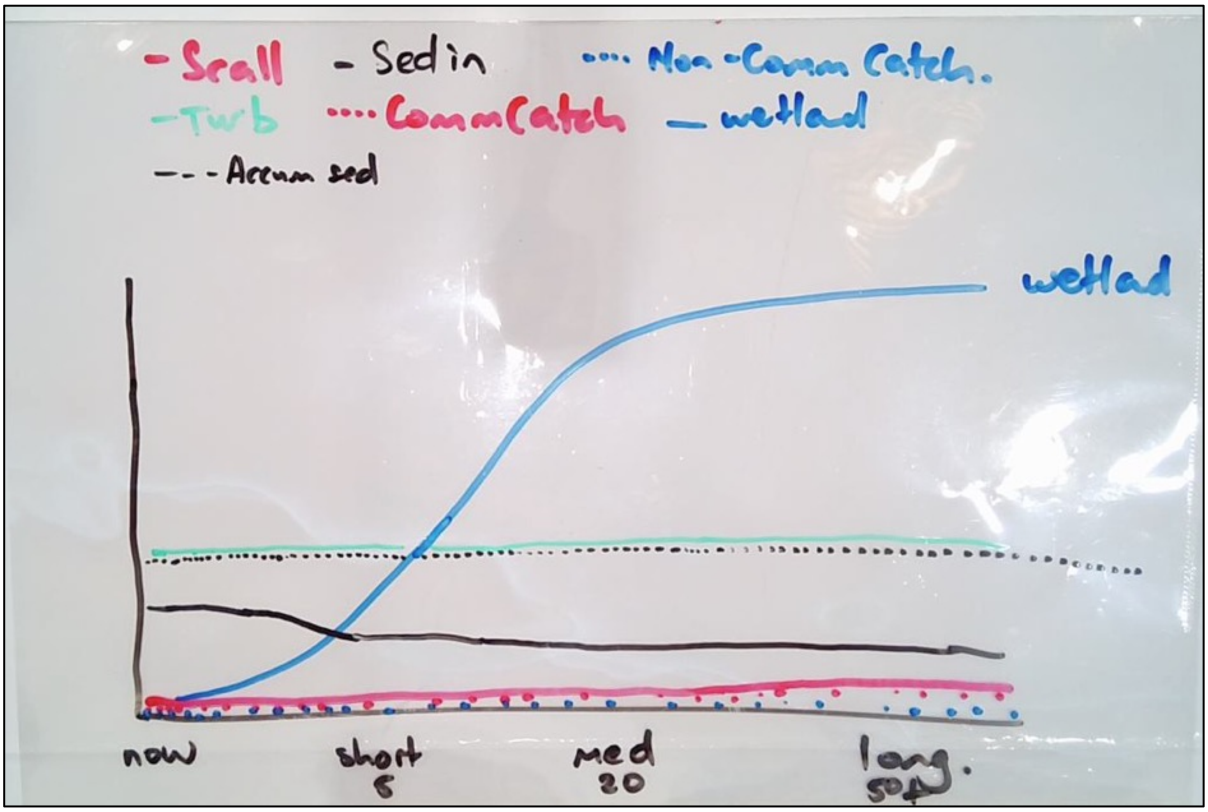
Each of the three interventions explored in this workshop are discussed below.

Firstly, pro-active restoration or addition of new wetlands was considered in order to reduce the sediment load going into the bay. The output graph from this discussion is shown in Figure 7.

The s-shaped curve in blue represents a cumulative amount of restored wetland. An s-shape was suggested as it may take some build time to build traction and awareness of such an initiative over the first 5 years. Then more restorations were likely to occur over the 5- to 15-year window as they became more widespread and popular, possibly in response to subsidies or direct funding. Finally, nearing the 20-year mark, the curve begins to level off again. This represents the likelihood that after 20 years most restorable wetland areas were likely to have been restored and there would be less possibility for areas to be converted, or late-adapters would finally all convert.

During discussion, the group talked about the fact that while the increase in wetlands may reduce the amount of sediment entering the bay by a small margin (note the slight dip in the black line), it was unlikely to do anything about the turbidity (green line) and the level of accumulated sediment that was already in the bay (dotted black line). This is primarily because reducing the incoming sediment load would not itself decrease the amount of the accumulated sediment that was already there. Further, the bottom disturbance from trawling (not shown as a line on the graph) would continue to disturb the seabed and thus continue as a cause of turbidity. Commercial and recreational dredging for scallops (the red and blue dotted lines) would remain banned. All of this was unlikely to impact scallops, which remain as a very low line (solid red line) along the bottom of the graph.

__Figure 7.__ ***Anticipated behaviour over time of selected variables if wetlands were restored or constructed.***



Secondly, the construction or ‘seeding’ of 3D structure on the seabed was considered. This was seen as an important part of the habitat for scallops and part of wider seabed health. 3D structure provides important protection benefits for scallops during the recruitment phase of their lifecycle – providing more options for safety when young scallops ‘drop’. The output graph from this discussion is shown in Figure 8.

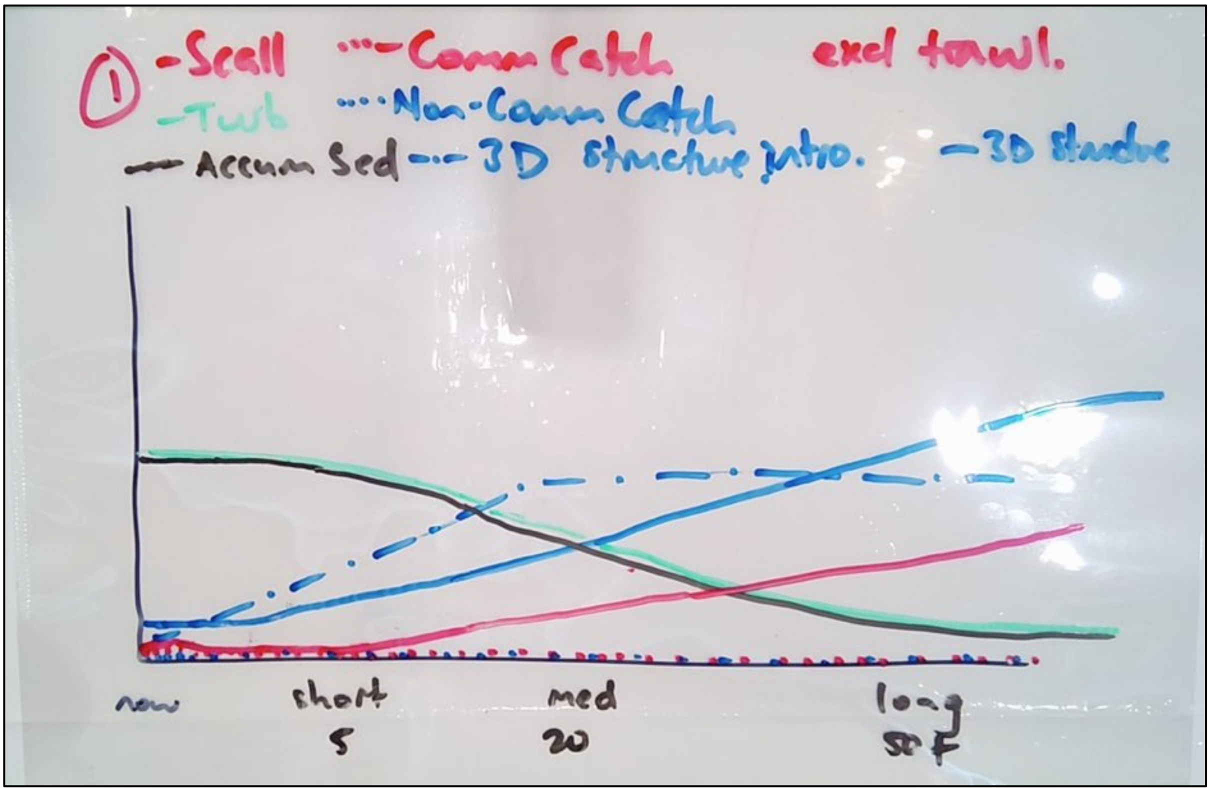
The intervention of adding artificial 3D structure is shown by the blue line-and-dot line. This was designed to represent an accumulation of introduced 3D structure, gradually increasing at a constant rate over a 20-year period and then levelling off once the active intervention ceased. As per the first example, commercial and non-commercial dredging (blue and red dotted lines) remains banned.

The discussion talked about how the introduction of 3D structure would slowly ‘cap’ the accumulated sediment (solid black line) that existed there, and then slowly increase the naturally occurring 3D structure (solid blue line). The development of both of these activities would result in a decrease in turbidity (solid green line). The rate at which this occurred was broadly expected to match the rate at which the 3D structure increased, and the accumulated sediment decreased (through this ‘capping’ process).[2]

[2] Section 3.5.1 mentioned that when finalising the system map in this final workshop, it became obvious that some people had interpreted some of the factors slightly differently. ‘Accumulated sediment’ was one of these factors and it was again highlighted in this discussion. The main confusion came from whether this factor referred to the *amount of* accumulated sediment in the bay, or to the *depth of* that

After a slightly longer delay, and probably increasing at a slightly slower rate, it was thought that the scallops would slowly make a return (solid red line). This was from enabling the naturally occurring spat (which remains plentiful in the bay) and the recruitment process of scallops dropping to the seabed, to land on appropriate seabed areas and then thrive. However, it was perceived that there was unlikely to be any significant progress within a 5-year period, and only slight progress after a 20-year period. So, it was acknowledged that while this intervention might have some desired impact, it was likely to be after a very long time-delay.

Figure 8. ***Anticipated behaviour over time of selected variables if 3D structure was constructed on the seabed.***



Finally, the banning of bottom contact fishing methods (both trawling and dredging) was considered. It was noted that this would be a highly controversial intervention given the prominent role that fishing plays in the local economy. The output graph from this discussion is shown in Figure 9.

All bottom contact fishing methods (fin-fish trawling, commercial and non-commercial scallop dredging) are represented by the dotted red line, which is constantly at zero on the graph. When the group discussed this, it was considered that there would be a definite and fairly

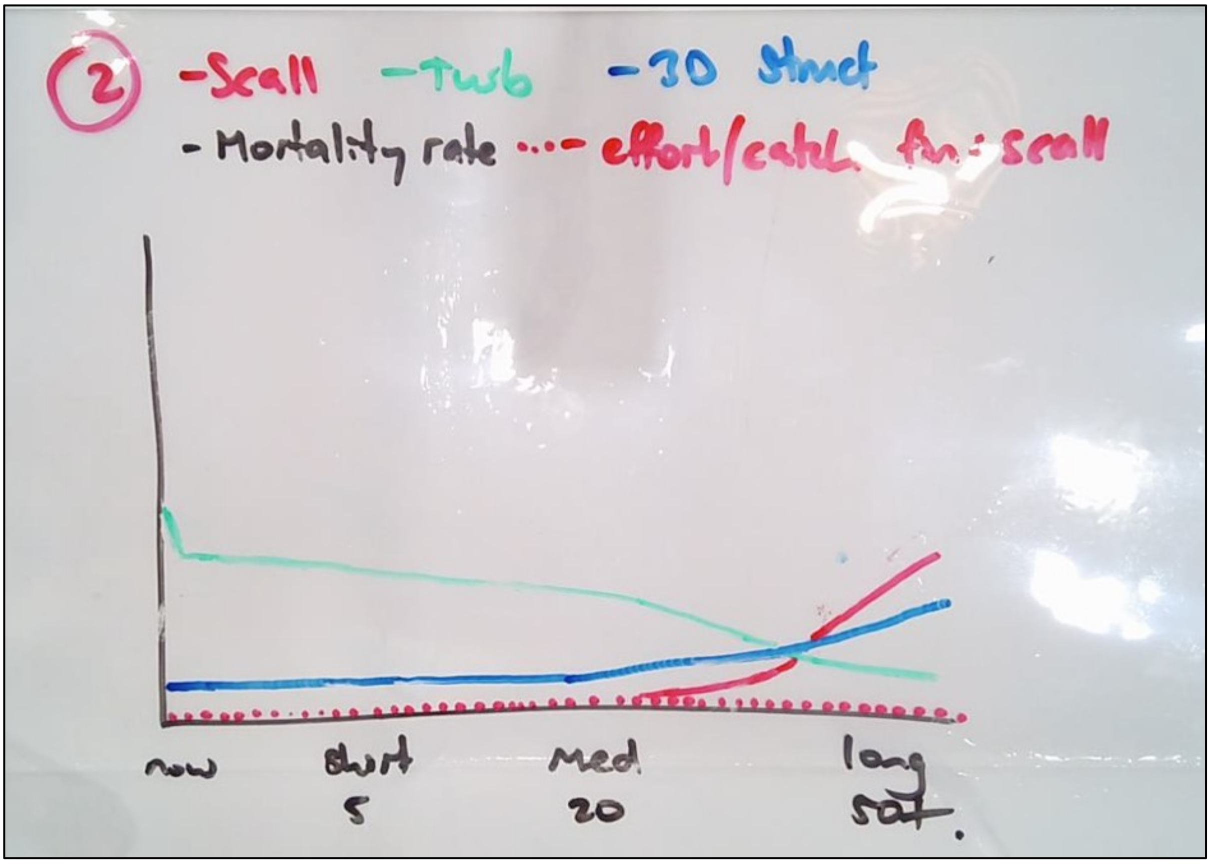
---

sediment. Technically, if adding 3D structure to the seabed 'capped' the sediment, it was not going anywhere, so the same amount remained. However, the accessible depth of it on the seabed interacting with the water and tides etc was reduced or effectively eliminated, because it was now *under* the 3D structure. While this may a trivial difference, it highlighted the importance of being clear what factors meant. It also highlighted the need to keep a record of these descriptions accessible for all to refer to, if needed.

immediate effect on turbidity (solid green line), with it reducing at least partially in as little as several weeks to several months. This was due to the cessation of disturbance from bottom contact fishing. Yet that is not the only factor contributing to turbidity. The ongoing natural processes of tides and wave action; the ongoing sediment-load from the land; and the large amount of accumulated sediment that is already on the seabed; would all contribute to ongoing turbidity. Therefore it was expected that after this initial drop in turbidity, these processes would continue, turbidity only very slowly being reduced by the natural process of horizontal transportation. This would progress for many years, possibly several decades, before the turbidity reduced enough for 3D structure (solid blue line) to naturally return.

When 3D structure did return it would do so slowly, yet as some 3D structure was established this would reinforce the ability for more to generate and it would increase more rapidly. This would have a corresponding impact on turbidity, which was likely reduce more quickly once 3D structure began to accumulate. Once both of these occurred then the scallops were likely to slowly re-establish. It was noted that this would be a slow process and may take several decades to develop significant numbers, this after possibly taking several decades to even begin to re-establish.

Figure 9. Anticipated behaviour over time of selected variables if all bottom contact fishing methods (dredging and trawling) were banned.



3.5.4 Summary of Workshop 3

Previous sub-sections have described the process of Workshop 3. This section outlines some observations of this workshop from the facilitator.

Workshop 3 was where the system mapping pilot ‘came together’. It was a culmination of the discussions from earlier workshops and the application of the draft system map that had been drawn by the participants, to explore the anticipated future behaviour of key variables.

While many participants had found the initial workshops confusing and even maybe frustrating, discussion amongst participants at the end of the third workshop indicated that most participants had found the overall process stimulating, interesting and useful. Even participants who specialised in scallops as a subject matter, commented how they had not appreciated how interconnected everything actually was.

The graphing exercise was very well received and once again the visual stimulus helped to support an interactive and engaging discussion. Many participants commented that the dynamic outputs of the graphs, even though it was highly subjective, were useful and helped provide insight to the issue.

There was general agreement that the process had highlighted that it was likely that a number of interventions would be required in conjunction with each other – not simply banning bottom contact or increasing 3D structure, for example. This is not surprising. The three interventions chosen were selected only as a way of exploring the application of the systems mapping tool. It is not suggested that this tool would only result in one intervention, multiple would be likely and can also be qualitatively explored.

One final thing that was noted by the facilitator was that many participants did not refer to the A1 print-out of the system map. While the intention was to trace causality on the map during discussions, the fact that this did not happen does not mean that the map had not influenced the participants mental understanding of the system (their mental models). It can only be speculated as to whether it did or not.

4 Summary of survey data from participants

This section summarises data gathered from two different participant surveys. Firstly, an identical survey was carried out before the first workshop and after the third (pre-test/post-test), which was a means of exploring whether people's *mental models* had changed at all from the workshops. Secondly, another survey of participants was carried out after the final workshop to gain insights into participants' *experience* of the workshops process.

4.1 Survey to assess possible mental model change

Participants' mental models, or how they understand the world to operate, is at the core of trying to build a system map (Senge, 2006, Sterman, 2000; van den Belt, 2011) like that built in this pilot. Understanding the impact that a participatory process may have on participants' mental models is important to understand, yet difficult to demonstrate (Scott et al., 2016).

One way of doing this is to undertake a pre/post-test survey (immediately before the first, and immediately after the final workshops) asking participants to identify factors that influenced the behaviour of interest (Scott et al., 2013). This was the approach used in this pilot and was undertaken to try to determine if there had been any *immediate* change in participants' mental models.

This process also allows for the possible re-surveying of participants with the same survey sometime within approximately 3-12 months of the final workshop, to determine if there were any *enduring changes* to participants' mental models (Scott et al., 2013).

A copy of the pre/post-test survey given to participants is in Appendix 3.

A simple quantitative content analysis was undertaken on the factors listed in these surveys. This quantified both the *total number of factors* that were listed, and the total number of times that a *certain type of content* was listed. Many answers (both pre- and post-test) mentioned a range of inter-related factors and their sequence of cause-and-effect. In order to mitigate the potential confusion regarding this the dominant words listed in these factors were used as the key identifier for what the factor was listing. For example, "Bottom contact fishing leading to resuspension of fine sediment and turbidity" was grouped within the *Bottom disturbance from trawling/dredging* content category. The results of this analysis are shown in Table 1.

Table 1. Content analysis of pre/post-test surveys to determine if mental model change had occurred

Content (from dominant words within listed factors)	No. times mentioned	Graph
Pre-first workshop		
Bottom contact fishing	9	
Sedimentation	8	
Seabed health	6	
Over fishing	4	
Impacted scallop population	3	
Pollution	3	
Land use change	2	
Other	6	
Total factors mentioned	41	
Post-final workshop		
Sedimentation	8	
Bottom disturbance from trawling/dredging	7	
Lack of suitable seabed habitat	5	
Over fishing	4	
Turbidity	3	
Lack of widespread understanding and support of issue	3	
Land use change	2	
Other	3	
Total factors mentioned	35	

In addition to looking at these data from an aggregated view, we can also look at individual responses. The number of factors listed by each respondent before and after the workshops is graphed in Figure 10. The theme content is listed, by respondent, in Table 2. Here the variables listed by participants have been replaced by the *theme* that they were allocated into during the content analysis. This helps to preserve the anonymity of the participants.

Figure 10. ***Number of variables listed by respondents before the workshops compared with after the workshops.***

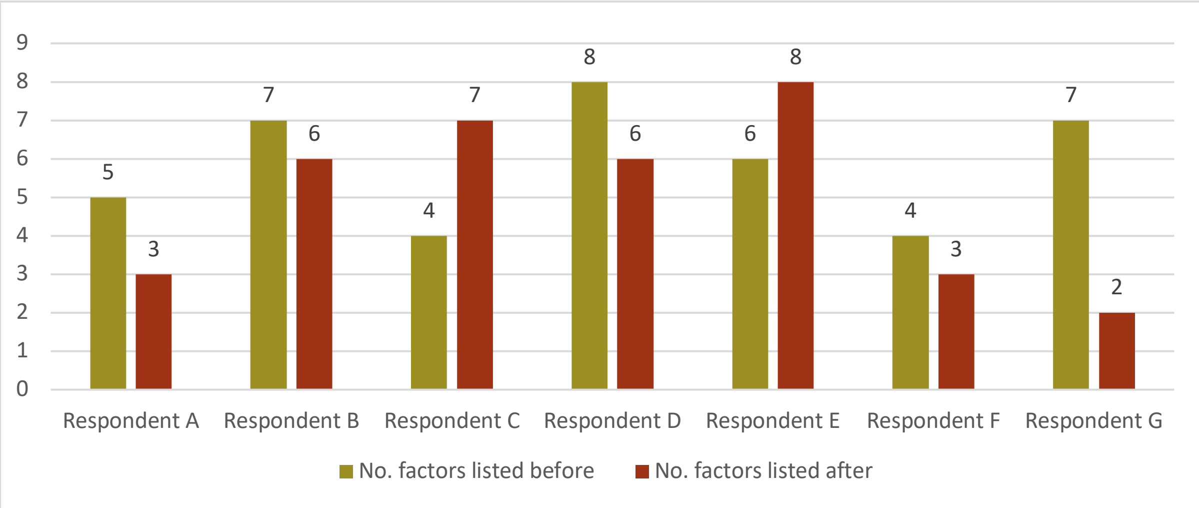


Table 2. ***Content themes of the variables, listed by respondent.***

	Survey 1: Pre-first workshop	Survey 2: Post-final workshop
Respondent A	Sedimentation Sedimentation Bottom contact fishing Bottom contact fishing Bottom contact fishing	Sedimentation Bottom disturbance from trawling/dredging Lack of suitable seabed habitat
Respondent B	Other Pollution Other Pollution Land use change Over fishing Other	Sedimentation Over fishing Other Other insufficient social dynamics Land use change
Respondent C	Sedimentation Bottom contact fishing Seabed health Impacted scallop population	Sedimentation Bottom disturbance from trawling/dredging Bottom disturbance from trawling/dredging Turbidity Lack of suitable seabed habitat Lack of suitable seabed habitat Turbidity

	Survey 1: Pre-first workshop	Survey 2: Post-final workshop
Respondent D	Over fishing Bottom contact fishing Sedimentation Bottom contact fishing Seabed health Seabed health Impacted scallops Seabed health	Over fishing Bottom disturbance from trawling/dredging Lack of suitable seabed habitat Sedimentation Over fishing Sedimentation
Respondent E	Sedimentation Over fishing Pollution Seabed health Over fishing Other	Sedimentation Sedimentation Other Over fishing Bottom disturbance from trawling/dredging insufficient social dynamics insufficient social dynamics Land use change
Respondent F	Sedimentation Bottom contact fishing Bottom contact fishing Sedimentation	Sedimentation Bottom disturbance from trawling/dredging Turbidity
Respondent G	Sedimentation Bottom contact fishing Impacted scallops Seabed health Land use change Other Other	Lack of suitable seabed habitat Bottom disturbance from trawling/dredging

**The content themes listed above are those from the content analysis. The actual variables listed by respondents has been exchanged for the theme that it was grouped into. Variables are listed in the order listed by the respondent.*

There were less factors listed after the workshops than before, a total of 41 before compared to 35 afterwards (see Table 1). This decreasing trend was also reflected in five of the seven individual respondents – only two *increased* the number of variables that they listed (see Figure 10 and Table 2).

Both these aggregated and individualised data indicate that there was not any significant immediate impact on the *type* of factors in participants' mental models, as many of these remained the same. This is consistent with the qualitative comments that participants made in the feedback survey (section 4.2) and during discussions that project staff had with participants. Many participants commented the 'there was nothing new' when talking about the factors, or that the resulting factors 'didn't surprise them'.

The pre-test/post-test survey did not ask participants to rank the variables, so the order they listed them should not be taken as a priority list. Yet the order in which they wrote them (as shown in Table 2) may provide *informal* insight into what variables were at the ‘top of mind’ for participants.

Most participants tended to list similar factors first, both before and after the workshops, with only one varying majorly from this – perhaps indicating a more significant change in mental model for that participant.

What these data may indicate is that while the *type of content* may not have changed much, the reduced numbers may have helped focus participants attention to those that they believed were *most influential*. After the final workshop some participants seem to have discarded some variables, which they would have included previously, or aggregated others, possibly indicating a reduction in the importance of these in their mental models.

These insights raise two important questions. Firstly, as this was a pilot, it was a smaller group that was purposively sampled, in part based on their perceived subject matter knowledge; their organisational/cultural perspective; and their availability at relatively short notice. The first of these selection criteria is the most important here; while a couple of participants did not have a *strong* knowledge of scallops, most participants already had a moderate-to-reasonable knowledge of these issues. If this process is run again the future it will be useful to compare these results with those from a wider range of stakeholders.

Secondly, qualitative feedback from participants in the feedback survey (section 4.2) indicated that most participants gained new knowledge, but that this was more focused around *how the factors were inter-connected with each other*, rather than what the factors were themselves (although this may have been adjusted, as discussed above). As this mental model survey was focused on the factors listed by participants, this raises an important question: Should a survey designed to test for mental model change relate only to factors; or to factors *and inter-connections between each other?* This could be a research component of possible future applications of this method.

4.2 Survey feedback from participants about the process

This section summarizes participant feedback regarding their *experience of* the process. A copy of the feedback survey is in Appendix 4.

This survey contained 17 quantitative questions and seven open-ended questions. Of the qualitative questions, three were supplementary to some of the quantitative questions; while four were separate questions at the end of the survey. Seven surveys were completed after the final workshop.

The results of the quantitative questions are provided in in Table 3 and in graphical form in Figure 11. These overwhelming indicate that participants agreed with most of the statements in the survey.

The strongest disagreement was one person who did not consider themselves to have good subject matter knowledge before the workshops. The greatest number of people that disagreed with a statement was two; these participants disagreed that the process had resulted in new factors being considered (see also discussion in 4.1). One person (not necessarily the same person) disagreed with each of the following statements: the concept of systems mapping was easy to understand; they could see their contributions to the discussions in the system map; they would be willing to participate further in the development of this map; and that having experienced this pilot, they would be willing to invest in a similar process in another setting.

The strongest agreement amongst participants may be indicated where all participants checked either the strongest agreement box ('Strongly agree') or the next box down. This was the result for three of the questions: 8) Considering the system holistically will help support workable solutions/interventions; 11) I feel that my contributions to this process (i.e. knowledge, ideas and questions) were valued; and 16) I would recommend to others to participate if the opportunity arose to be involved in a similar process. The question that the most participants 'strongly agreed' with was also Question 8 – *Considering the system holistically will help support workable solutions/interventions* – which was checked by 5 participants.

These data provide evidence that participants had a positive experience of the process.

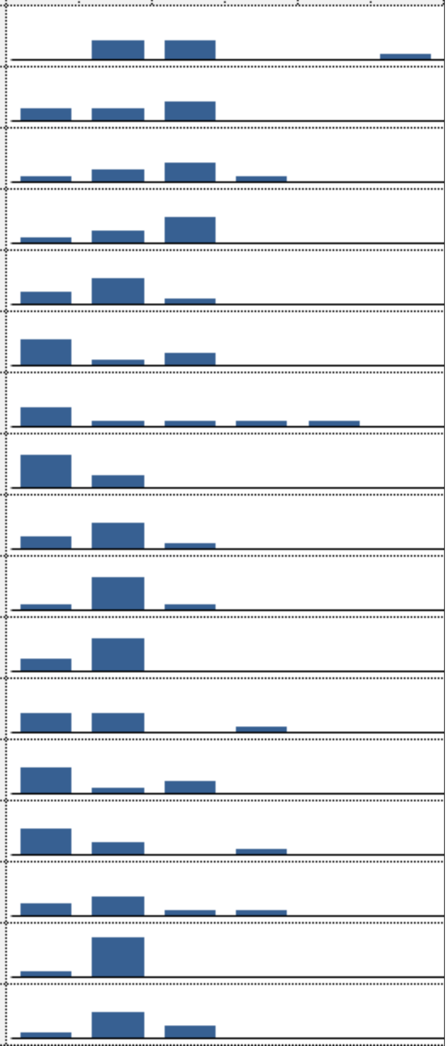
It is noted that two participants (of the original nine) were unable to fill in these feedback forms. One was only able to attend the first workshop; while another attended all workshops but not for their entire duration.

Table 3. Quantitative survey results of participants experience of the process – tabulated

	Question	Strongly agree					Strongly disagree
Q1	1. I believe my knowledge of the problem before the workshop was good. (Relative to the general audience)		3	3			1
Q2	2. I have gained new knowledge through my involvement in these workshops over the last few weeks	2	2	3			
Q3	3. I found the concept of systems maps easy to understand	1	2	3	1		
Q4	4. I found the process of creating a systems map easy to follow	1	2	4			
Q5	5. I think we (the participants) had sufficient opportunity to discuss the key issues through-out the process	2	4	1			
Q6	6. This process helped me better understand the perspectives of other people in the room	4	1	2			
Q7	7. I think this process has helped us to consider new factors that that we hadn't previously thought of that influence scallops in the Bays	3	1	1	1	1	
Q8	8. Considering the system holistically will help support workable solutions/interventions	5	2				
Q9	9. Acknowledging that this is a pilot process, I am comfortable with the system map we have generated	2	4	1			
Q10	10. I find it easy to make sense of the final systems map	1	5	1			
Q11	11. I feel that my contributions to this process (i.e. knowledge, ideas and questions) were valued	2	5				
Q12	12. I can see my contributions to the discussions in the system map	3	3		1		
Q13	13. This group has worked well together collaboratively to develop the map	4	1	2			
Q14	14. I would be willing to participate further in development of this map	4	2		1		
Q15	15. Having experienced this process creating a systems map, I would invest into a similar process in another setting	2	3	1	1		
Q16	16. I would recommend to others to participate if the opportunity arose to be involved in a similar process	1	6				
Q17	17. I think this approach would be useful in a real-world planning decision	1	4	2			

Figure 11. Quantitative survey results of participants experience of the process – graphed

	Question	Strongly agree					Strongly disagree
Q1	1. I believe my knowledge of the problem before the workshop was good. (Relative to the general audience)						
Q2	2. I have gained new knowledge through my involvement in these workshops over the last few weeks						
Q3	3. I found the concept of systems maps easy to understand						
Q4	4. I found the process of creating a systems map easy to follow						
Q5	5. I think we (the participants) had sufficient opportunity to discuss the key issues through-out the process						
Q6	6. This process helped me better understand the perspectives of other people in the room						
Q7	7. I think this process has helped us to consider new factors that that we hadn't previously thought of that influence scallops in the Bays						
Q8	8. Considering the system holistically will help support workable solutions/interventions						
Q9	9. Acknowledging that this is a pilot process, I am comfortable with the system map we have generated						
Q10	10. I find it easy to make sense of the final systems map						
Q11	11. I feel that my contributions to this process (i.e. knowledge, ideas and questions) were valued						
Q12	12. I can see my contributions to the discussions in the system map						
Q13	13. This group has worked well together collaboratively to develop the map						
Q14	14. I would be willing to participate further in development of this map						
Q15	15. Having experienced this process creating a systems map, I would invest into a similar process in another setting						
Q16	16. I would recommend to others to participate if the opportunity arose to be involved in a similar process						
Q17	17. I think this approach would be useful in a real-world planning decision						



The qualitative responses provided as supplementary to answers in quantitative questions is tabulated in Table 4. These responses expanded on why people had agreed or disagreed with questions relating to: whether they had gained new knowledge from this process (all agreed); whether they would invest in such a process again (only one disagreed citing the time & effort required); and whether they thought this process would be useful in a real-world planning decision (all agreed).

Qualitative answers from four open ended questions are tabulated in Table 5. The first question asked for general feedback and participants highlighted: their learning about the systems approach; how they had learned a lot or been surprised by the extent to which everything was connected; how the approach was seen as a good facilitation tool; and how the qualitative mapping of interventions in the final workshop had been particularly useful. The three other questions asked what participants thought: worked well; what they would change; and what they found challenging.

Table 4. Qualitative feedback that was supplementary to quantitative questions

<table>
<tr><th colspan="2">Answers that were supplementary to quantitative questions</th></tr>
<tr><th>Question</th><th>Summary of answers
(Number of respondents in brackets)</th></tr>
<tr><td>The statement in Question 2 was: "I have gained new knowledge through my involvement in these workshops over the last few weeks"

The question was then asked: "What is the new knowledge you have gained?"</td><td>All respondents agreed to some extent. Their answers are summarised as:
The systems mapping methodology was more familiar. (several)
Map allowed participants with low initial level of scallop knowledge to learn “a lot” about the influences on scallops. (several)
The extent to which influences of scallops were interconnected was highlighted. (several) One knowledgeable participant even expressed “surprise”. (one)
A participant knowledgeable about scallops did not learn much new subject matter, but they learned how important a tool like system mapping was for integrated system modelling/understanding. (one)
The utility of systems mapping as a facilitation tool was noted, as it helped to focus discussion. (several)
Graphing variables over time was useful. (one)</td></tr>
<tr><td>The statement in Question 15 was: "Having experienced this process creating a systems map, I would invest into a similar process in another setting"

The question was then asked: "Why is this?"</td><td>One person disagreed with the statement in Q.15. Their answer was:
Time/effort required. (one)
Six people agreed with the statement in Q.15. Their answers are summarised as:
Worked really well with committed group. (one)
Helped focus conversation and people learned a lot from it, were intellectually stimulated. (one)
Felt that in its current form it did not suit mapping a Te Ao Māori perspective. (one)
It could help groups understand, would be useful for stakeholders, or how it might aid communication. (several)
Outputs might be difficult to understand if you weren't involved. (one)</td></tr>
</table>

Answers that were supplementary to quantitative questions	
Question	**Summary of answers (Number of respondents in brackets)**
The statement in Question 15 was: **"I think this approach would be useful in a real-world planning decision"** The question was then asked: **"Why is this?"**	**All respondents agreed to some extent. Their answers are summarised as:** • This would be useful to demonstrate the interconnections, complexity, or holistic nature of issues. (several) • The process was engaging and stimulating AND also accessible and simple enough for assorted audiences to understand. (several) • More concrete evidence would be required for decision-making processes, but this process could still contribute to that in conjunction with other tools. (one) • This tool would likely be useful if a complimentary approach/tool was developed to complement, or help bridge to, the Te Ao Māori perspective. This would allow multiple world views to increase their understanding. (one)

Table 5. Qualitative feedback that was in response to open ended questions

Additional qualitative questions	
Question	**Summary of answers (Number of respondents in brackets)**
Thank you for your feedback. Any other comments?	**Four people responded. Their answers are summarised as:** • Positive comments relating to enjoying the exercise, finding it interesting, appreciating others points of view, or being a positive approach to science. (two) • This was likely to be more difficult with more polarised views and/or personalities in the room. (one) • The process had with accommodating Te Ao Māori/the Māori world view, yet it was also suggested that this tool may still be useful in this space, with more time or an appropriate complementary approach. (two)
Something that worked well in the process was	**Seven people responded. Their answers are summarised as:** • The structure of the process helped to: enable conversation; helping conversation flow - even though it was partly self-directed and amongst a technical audience; or making people feel comfortable contributing. (most) • The structure built up throughout the process, slowly building deeper understanding. (one) • The small size of the group was seen as useful by some, while others commented on the constructive dynamic of the group itself. (several) • The interviews/catch-ups between workshops were really useful. (one) • Reflecting back the system map that had been developed at the start of workshop was mentioned several times. One person found this a positive; another person found it useful, but possibly repetitive - although they acknowledged this was likely a personal preference and that it was likely to be useful for most people. • The visual nature of process was noted by several people. Drawing graphs of the interventions was seen as really useful by one; while the interactive visual nature of the map was a positive for several others.

<table>
<tr><th colspan="2">Additional qualitative questions</th></tr>
<tr><th>Question</th><th>Summary of answers
(Number of respondents in brackets)</th></tr>
<tr><td>Something that I would change about the process was</td><td>Six people responded. Their answers are summarised as:
The introduction to the workshops in the first instance could be better. (several)
Perhaps the journey of the process could be demonstrated with examples or a video. (one)
There is a need to set clear expectations of the process and how the output would be used. (several)
The need for better pre-planning from a Māori perspective was highlighted. Anticipating how a Māori perspective could contribute, so that this could be incorporated, was noted. Also the possible need for a facilitator to help in that space. (several)
The evening sessions were seen as challenging and tiring (several), although one person noted that they could leave the other cares of their 'work day' behind.
The process felt rushed. (one)
Wider stakeholder involvement or representation was necessary (several). While this would be useful it was also likely to be challenging (one).</td></tr>
<tr><td>Something that I have found challenging regarding the process was</td><td>Six people responded. Their answers are summarised as:
Having little subject matter knowledge made it difficult to contribute. (one)
Not having quantified data or evidence for each relationship described to be able to draw on, was a challenge. (one)
Those who commented favourably about the systems mapping process also noted that the systems concepts and terminology could be challenging, and were sometimes hard to understand. (several)
The time commitment and time of day that the workshops were held were challenging. (two)
Thinking through the complexity of all the relationships was difficult. (one)
If participants had set agendas or vested interests, that may make the process difficult. (one)
Everything was a challenge. (one)</td></tr>
</table>

5 Summary and recommendations for moving forward

This system mapping piloted an approach to understanding complexity using qualitative system dynamics tools. It is understood that this was a novel approach to all participants and most of the supporting researchers. The pilot was carried out with constrained time resources and a limited sample of participants who were purposively selected.

The constrained time and the fact that many participants were inconsistently involved in various other parts of the Science Challenge meant that most participants found the introductory workshop rushed and confusing. The Māori participants in particular felt uncomfortable as to whether a system mapping approach would be able to incorporate a Te Ao Māori perspective. Much of the context and introduction to the concept of systems mapping was then provided in the first follow-up interviews with participants, as well as exploring each of their areas of knowledge in more detail.

Having worked through some of these introductory issues and acknowledging that a separate workshop would explore the Te Ao Māori perspective, the second workshop was better focused around a draft system map. This helped clarify the insight that the approach might provide and engaged participants in a constructive discussion around refining the system map. It was observed that participants were generally more engaged after the second workshop.

Based on the holistic system understanding developed to date, the final workshop focused on qualitatively graphing possible interventions and the impact they may have on the key variables within the system. Some differing understandings of variables highlighted that any future process would need to be more comprehensive and possibly iterative. The exercise where the dynamics of the interventions were graphed seemed to be well received and appeared engaging for the participants.

Overall the observations of the facilitator and supporting researchers were that the systems mapping approach would be useful in future work on the Science Challenge. This was supported by data collected from participants in surveys.

A future process would benefit from being more comprehensive, requiring more time and resources. In addition, a range of specific recommendations are provided below. Some are direct recommendations and others are things that are less specific but need to be considered further:

Beginning/Introductions to workshops:

- Have a proper introduction to systems mapping/systems thinking
- Better describe the workshop process and the anticipated outcomes at the beginning, even when enlisting participants.

Timing and scheduling:

- Plan for system mapping workshop with more lead in time. Schedule them for times in the day that suit more participants better (which may still be evening).

- Maintain strong momentum for workshops – i.e. plan them out in advance in a reasonably close sequence (2-3 weeks apart). This will continue to ensure that as the approach is novel to many, subject matter or learnings are not forgotten between sessions.
- Participants should be kept consistent and not changed. They should also be encouraged to attend it person, where possible. While remote attendance may still be possible, in a comprehensive process this would likely be viewed as a disadvantage, particularly if a larger group was convened.

Further explore and seek to improve how Te Ao Māori may input to, or align with, systems mapping:

- Better prepare with the Māori world view in mind and whether it can be incorporated by, or inter-link with, a system map perspective. Subsequent to this pilot, a specific Māori workshop is planned for early 2019. This will explore if system mapping can be used to represent Te Ao Māori, or whether there is a way that 'bridges' of understanding can be built between a Te Ao Māori perspective and a system map.
- It may be useful considering how a Māori facilitator may support the group sessions.
- It will be important to explore how systems mapping may support a Te Ao Māori perspective, and it is acknowledged that this may result in two (or more) maps being developed. It is the perspective of the facilitator that if several maps were the result, care should be taken to as much avoid duplication between them as possible, so as to minimise confusion. A system map like that developed here provides an opportunity to represent the 'shared world' that both Māori and non-Māori occupy, even if they are viewed through different cultural lenses by both sides. This remains a subject for future research.

Utilise workshops and working-sessions:

- Utilise a balance of whole-group workshops and working sessions (interviews) with sub-groups or individuals, to develop different components of the map. What a suitable balance of each would be should be project-specific and dependent on the resource constraints of the project, and the levels of trust amongst the stakeholders involved. Group sessions help build trust amongst all members and more may be required to begin (Vennix, 1996; van den Belt, 2004), while smaller working sessions allow detail and complexity to worked through more efficiently.

Explore aggregation once insight to dynamics gained:

- It is often the experience of groups that some parts of system map, once developed in detail and the dynamics are understood, may be able to be condensed down to more simple structures that reflect the same basic dynamics. Future applications of this process may find it useful to incorporate this approach if they have more time and this is found to be the case.
- System archetypes (or 'common patterns') from the system dynamics literature that demonstrate common patterns of behaviour may prove useful in this regard (for examples of this see, Senge, 2006).

- This may also result in agreement around which parts of the system map need greater development or not. This will improve a shared understanding of where interventions would be best targeted.

Interventions and qualitative graphing exercise:

- Attempt to develop some historic qualitative trend lines of key variables, as well as estimating them into the future in the latter stages of the process. Developing these earlier in the workshops may enrich the discussion around factors and influences.
- Build the future trend lines together time period by time period (e.g. decade blocks?), rather than sketch them out one-by-one over the entire time frame. The objective here is that we are seeking to understand how the interconnectedness of each might affect the dynamics of the others. Therefore, sketching the dynamic behaviour over the entire time period of one variable *without* the others, may limit some of the insight gained. This will be especially true when multiple interventions are made.

6 References

Connolly, J.D. (2017). *Group model building to understand 'wicked' problems in New Zealand freshwater management* (Master's thesis, University of Waikato, Hamilton, New Zealand). Retrieved from https://researchcommons.waikato.ac.nz/handle/10289/11570

Deliberate. (2018). *Conceptual options for incorporating Systems Thinking into Project CP2.1 of the Sustainable Seas National Science Challenge*. Hamilton, New Zealand: Justin Connolly.

Ford, A. (2010). *Modeling the environment* (2nd ed.). Washington, D.C.: Island Press

Hewitt, J., Faulkner, L., Greenaway, A. & Lundquist, C. (2018). Proposed ecosystem-based management principles for New Zealand. *Resource Management Journal, November 2018*, 10-13. Retrieved from https://www.rmla.org.nz/wp-content/uploads/2018/11/RMJ-November-2018_copy.pdf

Ministry for Primary Industries. (2017). *Survey of scallops in SCA 7, January 2017: New Zealand Fisheries Assessment Report 2017/23*. Wellington, New Zealand: Williams, J.R., Parkinson, D.P., Drury, J., Roberts, C.L., Bian, R., Tuck. I.D.

Scott, R.J., Cavana, R.Y., & Cameron, D. (2013). Evaluating immediate and long-term impacts of qualitative group model building workshops on participants' mental models. *System Dynamics Review, 29*(4), 216–236. doi: 10.1002/sdr.1505

Scott, R. J., Cavana, R. Y., & Cameron, D. (2016). Recent evidence on the effectiveness of group model building. *European Journal of Operational Research, 249*, 908-918. doi: 10.1016/j.ejor.2015.06.078

Senge, P.M. (2006). The fifth discipline – the art and practice of the learning organisation (2nd ed). London, United Kingdom: Random House.

Sterman, J. D. (2000). *Business dynamics: Systems thinking and modelling for a complex world*. New York, NY, USA: McGraw-Hill.

van den Belt, M. (2004). *Mediated modelling: A system dynamics approach to environmental consensus building*. Washington, DC, USA: Island Press.

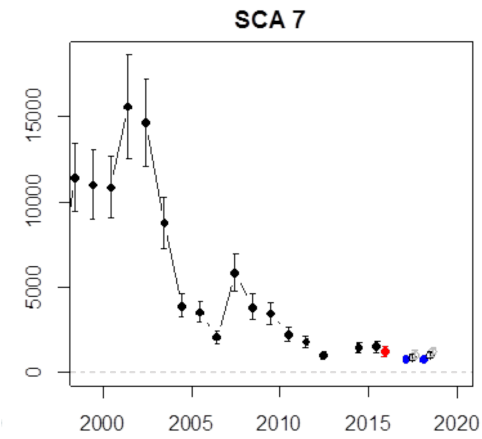
Vennix, J. A. M. (1996). *Group model building: facilitating team learning using system dynamics*: Wiley.

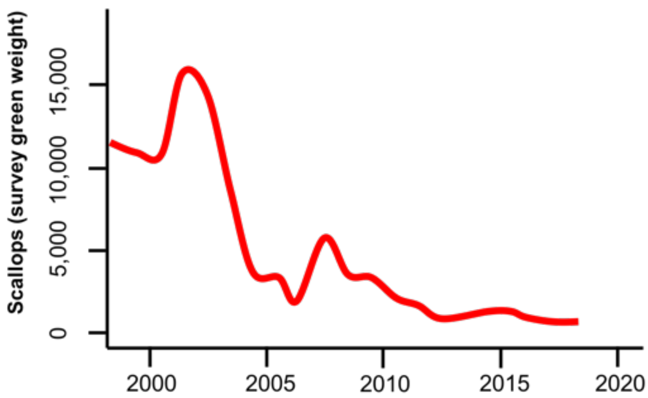
Appendix 1 Using the decline of scallops as a trend to focus the conversations

As noted in the report, a stylised graph of scallop decline (left) was used to focus the conversations in the workshop. This was generated from scallop green weight survey data collected over an approximately 20-year period and summarised in *Survey of scallops in SCA 7, January 2017: New Zealand Fisheries Assessment Report 2017/23* (Ministry for Primary Industries, 2017).

This imagery used is shown below. On the advice of Ian Tuck from NIWA, the SCA7 data was used. Although this incorporated Golden & Tasman Bays as well as the Marlborough Sounds, the Marlborough Sounds survey data was not considered large enough to make significant impact on the trend data.

A stylised graph was used in order to avoid unnecessarily detailed discussion that might be generated from a more detailed map.





Appendix 2 Draft system map developed in this pilot

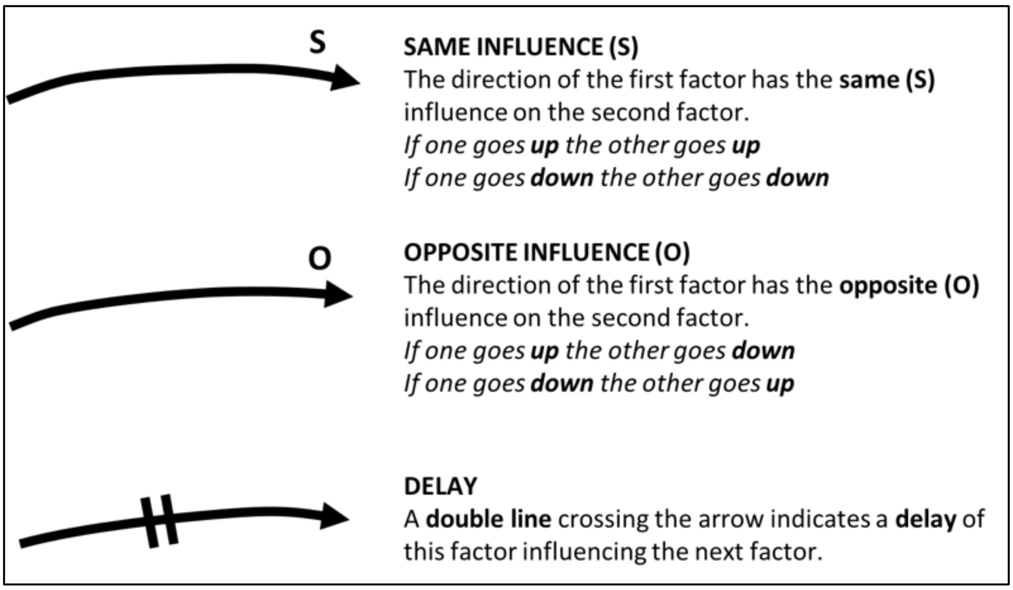
Preamble to description of the draft system map.

This appendix explains the detailed system map in more detail. While the entire map is shown in the main body of the report, and also reproduced in this appendix, the various parts of the map are described in a more detail here. This will be done by displaying segments of the overall map and describing the broad ‘theme’ of that area. A table with more detailed descriptions of each factor is also provided at the end of this appendix.

When reading a systems map, the fundamental architecture of System Dynamics should be kept in mind. These are: how factors are described; the markings used to describe the links between factors; and how factors can be linked into feedback loops. Some discussion of this occurs in section 3.3, and a comprehensive description is found in the previous report: *Conceptual options for incorporating Systems Thinking into Project CP2.1 of the Sustainable Seas National Science Challenge* (Deliberate, 2018). A brief overview of these fundamentals is provided here.

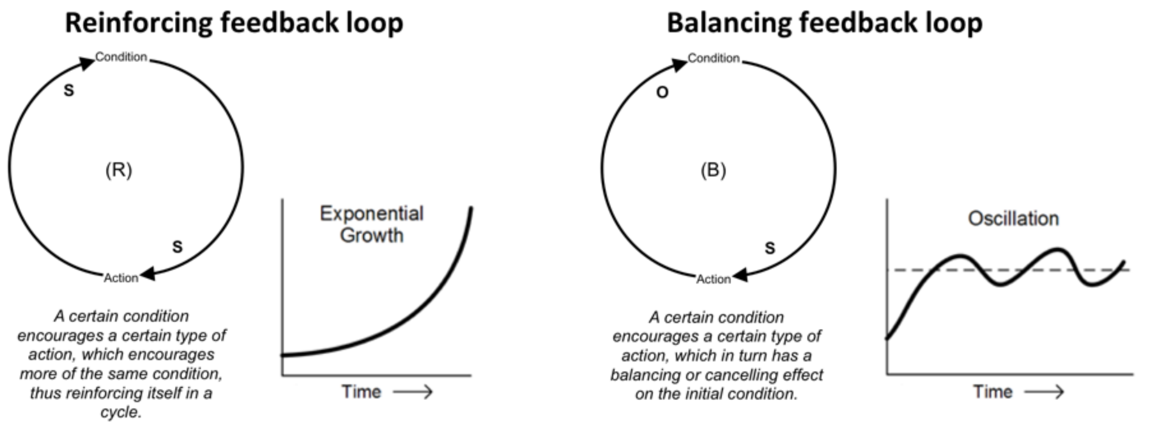
Firstly, it is important to describe factors in non-qualitative ways. That is, they should be described in such a that they can *increase or decrease*. For example, *Good water quality* is qualitative and should be avoided as it would cause issues with clarity of understanding if it was decrease. Can *good water quality* decrease? Instead, an appropriate label would be simply *water quality*, as this can improve or decline.

Secondly, the arrows between factors are described in terms of *Same (‘S’)* or *Opposite (‘O’)*, which is again *quantitative not qualitative*. See box below.



If one factor moves in one direction (either up or down) and the factor it influences moves in the *same direction*, then it is a *same influence (‘S’)*. Similarly, if one factor moves in one direction and factor it influences moves in the *opposite* direction, this is an *opposite influence ('O')*. These simply refer to the direction of change of the factors (quantitative), not whether that change is a desirable thing or not (qualitative). Short double line crossing an arrow indicate a delay in this influence occurring. These are not quantified and simply a way of demonstrating how some influences will take comparatively longer than others.

Thirdly, factors can be connected into chains of causality that feedback on themselves. These are known as *feedback loops* and are the basic building block of Systems Maps. These are described in Figure 4 in the report, which is reproduced below. Reinforcing loops feedback on themselves in the *same* direction, thus *reinforcing* the behaviour within that loop. Balancing loops feedback on themselves in the *opposite* direction, thus *balancing out* the behaviour within the loop.



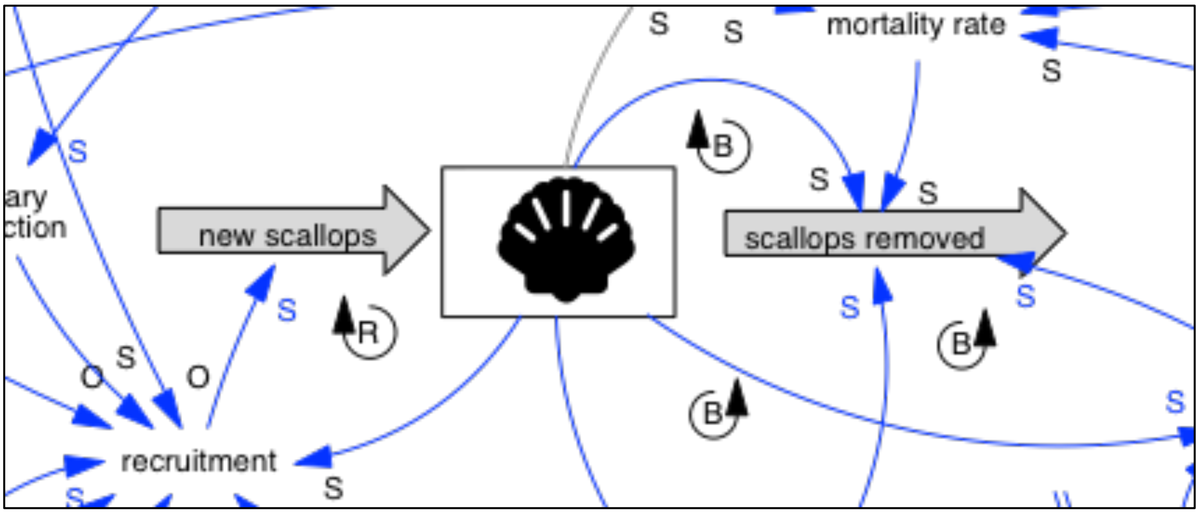
Adapted from Senge (2006) and Ford (2010)

Before describing the map, it is again stressed that as this was a pilot and there was limited participation, the system map developed should be considered draft. It is not put forward as a completed or comprehensive system map. A comprehensive process would be required to achieve a level of comfort (with a greater number of participants) where this was possible.

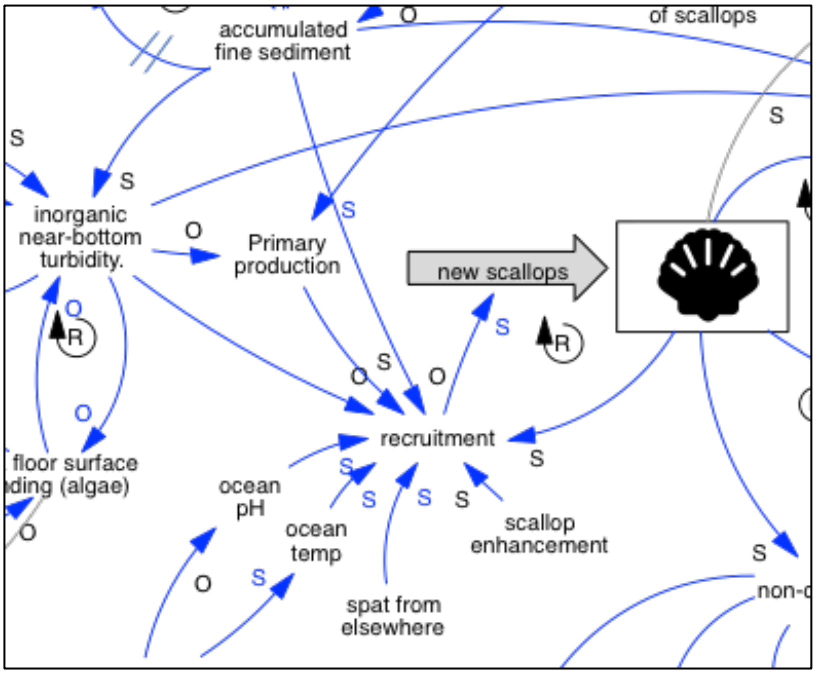
All relationships in this system ma are simplified (aggregated) in order to enable so much to be incorporated into one map.

Description of the draft system map.

The system map is centred around a box representing the population of scallops (shown as a scallop shell in a box, below). Put simply, scallops increase when new scallops are born (through the process of spawning, recruitment and settling). This is represented by the arrow labelled *new scallops* on the left-hand side of the box and going *into* the box. The number of scallops decreases when scallops (of any age) are harvested, killed, or die. This is what is represented by the arrow labelled *scallops removed* on the right-hand side of the box going *out* of the box.



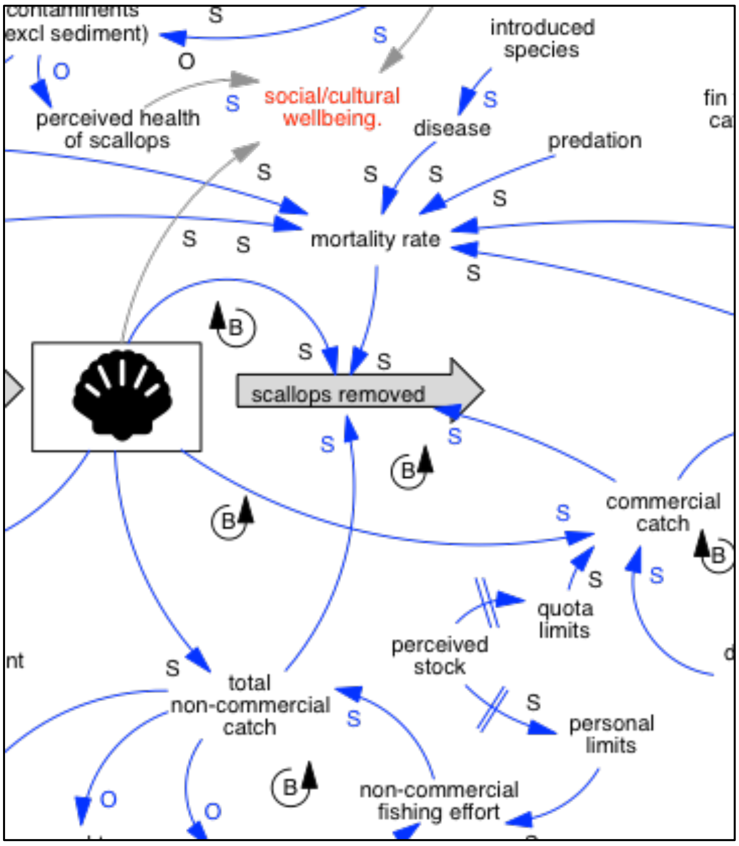
The arrows in the above image show that, the larger the number of scallops the greater the potential for recruitment, therefore more *new scallops* (a reinforcing loop). Also, the larger the number of scallops the greater the potential for mortality (even when a consistent mortality rate is applied), thus resulting in more *scallops removed* (a balancing loop). These are the basic dynamics of almost any population of anything, unmodified by human activity.



In this map *recruitment* (left) has been used as a general term to cover the early life-cycle of a scallop. It covers more than simply the settling of spat and dropping of baby scallops. This was one sacrifice of summarisation that was made to simplify the diagram.

The factors that were seen as influencing recruitment (above) and therefore *new scallops* were: primary production; spat from elsewhere; scallop enhancement; inorganic near-bottom turbidity; the accumulated fine sediment in the bays; and ocean temperature and pH levels.

The factors that influence mortality rate naturally are disease and predation (below). Disease may also be influenced by introduced species. Two other factors that also influence this (shown out of picture from the left – see complete map) are *inorganic near-bottom turbidity* and *accumulated fine sediment*. Two anthropogenic factors (from out of picture on the right – see complete map) are *trawling effort* and *discarding*. That is, these activities can affect the mortality of scallops not caught as part of the catch.

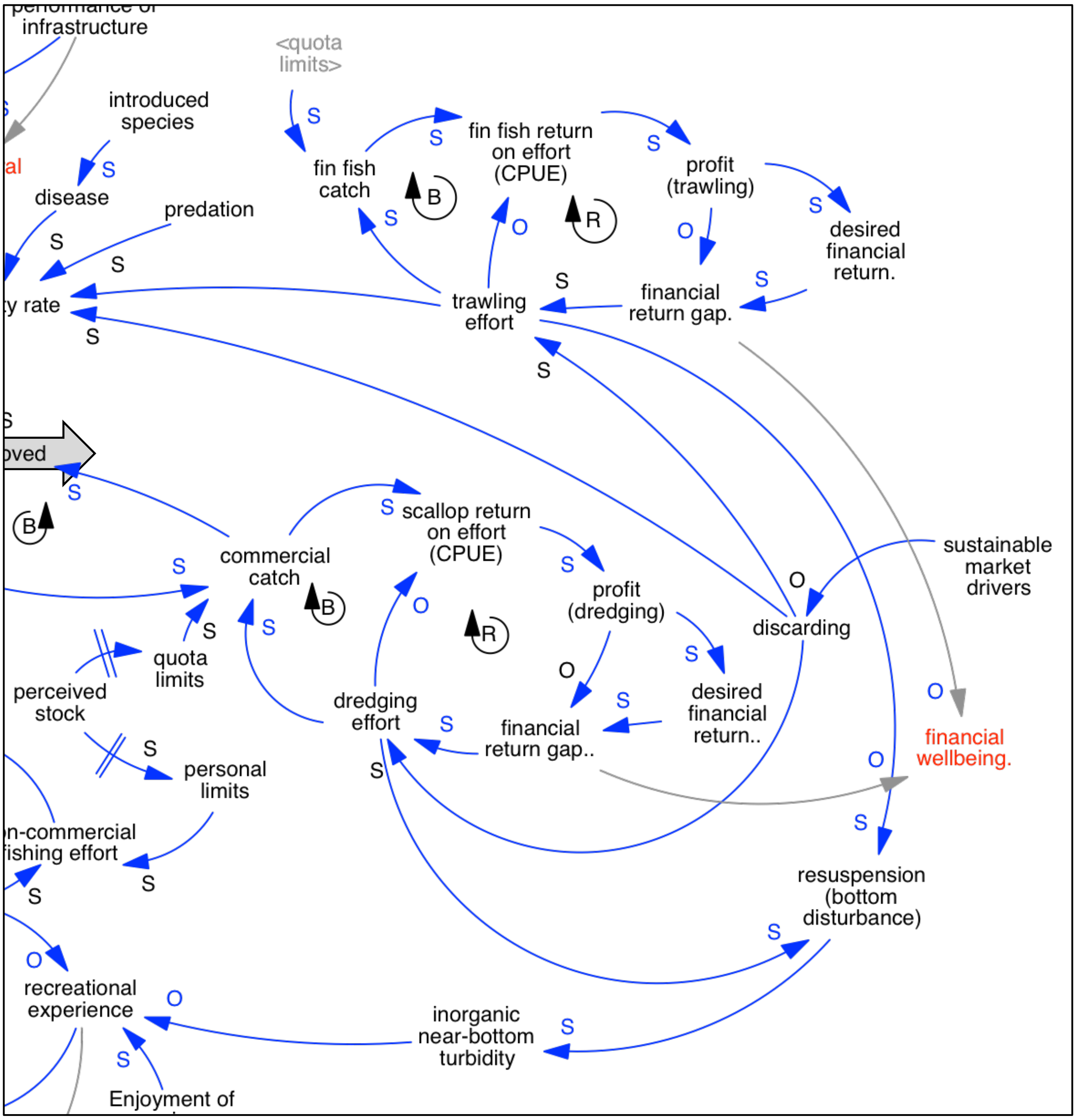


Similarly, scallops are also removed from the population not just through mortality, but through harvesting by humans (commercial and non-commercial catch) (left). These two factors create two additional balancing loops. In these, an increase in the level of scallops will increases the (non)commercial catch (for the same effort applied), which removes more scallops. In turn this reduce the population again, which in turn will reduce the catch (for the same amount of effort) and so on.

The perception of the stock level influences both the commercial limits (quota limits) and non-commercial limits (personal limits) established under the Quota Management System (QMS). The double lines on these arrows indicates that there is a delay operating between when a stock is perceived to change and when QMS limits are updated. This may be because several years of consistent survey data are needed to change a limit, or because it needs to go through a bureaucratic or political process.

Two types of commercial fishing are represented in the map (next page). Commercial fin fishing (trawling) is the upper set of loops, while the commercial scallop-catch (dredging) is the lower set of loops. Both have the same fundamental structure of two inter-connected feedback loops – one reinforcing and one balancing.

The balancing loop shows that greater trawling/dredging effort leads to greater catch (assuming no change in the number of fish/scallops in the sea), leading to a greater catch per unit effort (CPUE), more profit, a lowering of the gap between desired and actual financial return, which in turn takes of some of the pressure for trawling/dredging effort. As the effort reduces, the influences balance back through the loop in the other direction, decreased CPUE and profit, thus increasing the gap between desired and actual financial return again, in turn encouraging more trawling/dredging effort to decrease this financial gap.



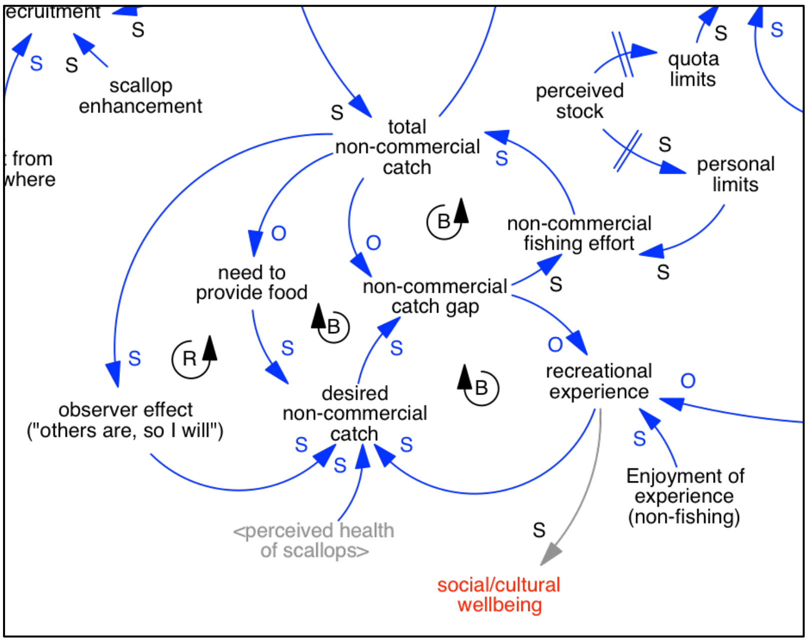
The influence of profit on desired financial return adds some complexity to this loop, as it allows them both two paths to go from profit. This alternate path has a *same* influence on the desired level of financial return. This structure indicates that, while increased profit decreases the gap between actual and desired financial returns, it also concurrently puts *upward pressure* on the level of desired financial returns – i.e. high profits increase your expectations for what your possible financial return could be.

Similarly, this structure may provide for a lowering of desired financial expectations if profit is consistently low. Although there may be a delay associated with this that has not been marked on the map. In short this structure adds an additional dynamic to the balancing loop that influences the fishing effort.

The reinforcing loop in this structure describes how, while the balancing loop produces a *fluctuating* CPUE, greater trawling/dredging effort always adds to the 'per unit effort' part of CPUE, thus always pressuring it downwards. Regardless of the fish caught this will result in *downward pressure* on profit, in turn *increasing* the financial return gap (the difference between desired and actual financial return). These combined influences will generate complex dynamics within the fishing industry that are driven primarily from the signal of actual fish caught, up to a point where the quota limit is reached, which will cease any further fishing effort.

The non-commercial section of the map is now considered in more detail (following).

The loop driving fishing effort is similar to the commercial section. A greater fishing effort leads to greater catch, which decreases the gap between desired catch and actual catch, thus reducing the overall fishing effort. While this structure of *desired* and *actual* catch is similar, the *desired catch* is driven by more factors. Where commercially this had been profit, here it is *the need to provide food*, *the perceived health of scallops*, the *recreational experience* and what was termed the *observer effect*. Here, fishers may see others successfully fishing and thus be encouraged to fish themselves. The dynamics of three of these are worth describing in more detail, as they are all examples of the type of complex behaviour that system maps can demonstrate.



Firstly, the ***need to provide food***. An increased need to provide food will increase the desired catch, which increases (in turn) the catch gap, fishing effort and (all other things being equal) the catch. With a good catch there is less *need to provide food*, thus this is a **balancing loop**.

Secondly, the ***observer effect ("others are, so I will")***. An increase in observing other fishing will increase the desired catch of those not fishing (i.e. "I want some too!"). In turn this increases the catch gap, the fishing effort (encouraging more people out fishing!), the actual catch, which in turn will increases the impact of the observer effect – as more people are out fishing. Together all these influences form a **reinforcing loop**.

Thirdly, the ***recreational experience***, where two balancing loops interact together (see above). These two loops describe the part-impact that the actual catch has on the recreational experience, which is also influenced by simply enjoying the experience (e.g. the enjoyment of going diving) and the impact of the environment on the experience (e.g. if turbidity is high people are less likely to enjoy diving – regardless of what they catch). The greater the catch gap (the less fish you catch compared to desired/expected) the less enjoyment (recreational experience), therefore the lower expectations (the lower desired catch as you may not want to go out diving as much), which in turn reduces the catch gap.

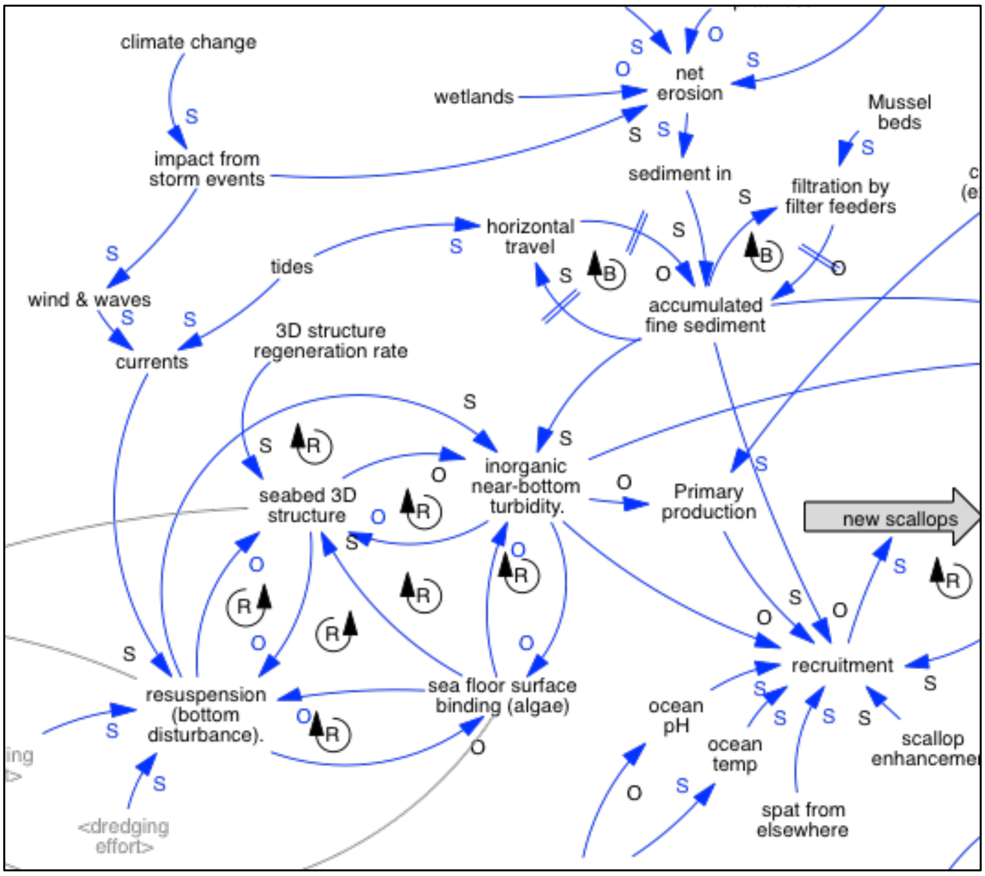
At the same time the primary non-commerical fishing effort loop continues to operate (made up of fishing effort > catch > catch gap and back to > fishing effort again). Therefore, the greater the effort, the greater the catch, the lower the gap between desired and actual – and vice versa on the next round.

The influences that these two *balancing* loops have on each other can also be described by following the influences as a figure eight through the structure. That is, a high recreational experience is likely to lead to an increased desired catch and therefore a *greater* catch gap. In turn this leads to more fishing effort, a greater catch and a *reduced* catch gap, which in turn leads to an *increased* recreational experience. Interestingly, when these two ***balancing loops*** operate together in this way, they become a ***reinforcing influence*** on the recreational experience. This is likely to put continuing *upward pressure* on the desired non-commercial catch at the same time as the other loops described are putting *downward pressure* on the same factor.

All of these above structures describe drivers of non-commercial fishing effort. The only *limit* on the non-commercial catch is the personal limits imposed by the fishing regulations (e.g. personal bag limits).

It is worth noting that both the commercial *quota limits* and the non-commercial *personal limits* are both influenced by the *perceived stock*. There is a delay (double-lines on the arrow) from the perceived stock to both these limiting mechanisms. As noted above, this represents the delay that occurs between determining the perceived stock and taking action if the limits need adjustment. For example, several years of consistently low stock surveys may be required before fishing limits are lowered. Similarly, increased stock numbers may need to be observed for some time to ensure that an increase to fishing limits is not premature and will not have a detrimental impact on stock numbers in the longer-term.

The area of the map that connects a range of factors that are considered part of seabed health is now considered (to the left of the complete map and shown as a sub-section on the following page).



To the left of the map there is a dense cluster of inter-connected factors that describe a range of influences on elements of seabed health. The main factors in this are *inorganic near-bottom turbidity, seabed 3D structure, sea floor surface binding (algae)*, and *resuspension (bottom disturbance)*. These are discussed in turn, below.

Inorganic near-bottom turbidity describes the amount of fine, inorganic sediment that is suspended in the water column, close to the sea floor. Hence this is influenced by the amount of fine sediment on the seabed and the extent to which that is resuspended. When there is a lack of 3D structure on the seabed and algae that help bind the surface of the sediments together on the seabed – there is a greater likelihood of resuspension. Increasing *inorganic* turbidity will also reduce primary production of shellfish, as they feed on *organic* matter suspended in the water column, so their ability to feed is reduced. This will have flow on impacts to recruitment.

Seabed 3D structure is reduced by the amount of bottom disturbance that occurs – i.e. the trawling and dredging effort. The regeneration of 3D structure only occurs after the initial binding of the seabed by algae, and both the algae and the development of 3D structure itself is inhibited by the level of inorganic near-bottom turbidity. This is because both the algae and the animals that create 3D structure feed on *organic* matter, so *organic-turbidity* can aid these things, and *inorganic turbidity* impacts on this. Hence the factor of *inorganic near-bottom turbidity* has been represented as this is the most important. The rate at which 3D structure is regenerated is also an important factor, and this is likely to be a slow rate, at least initially.

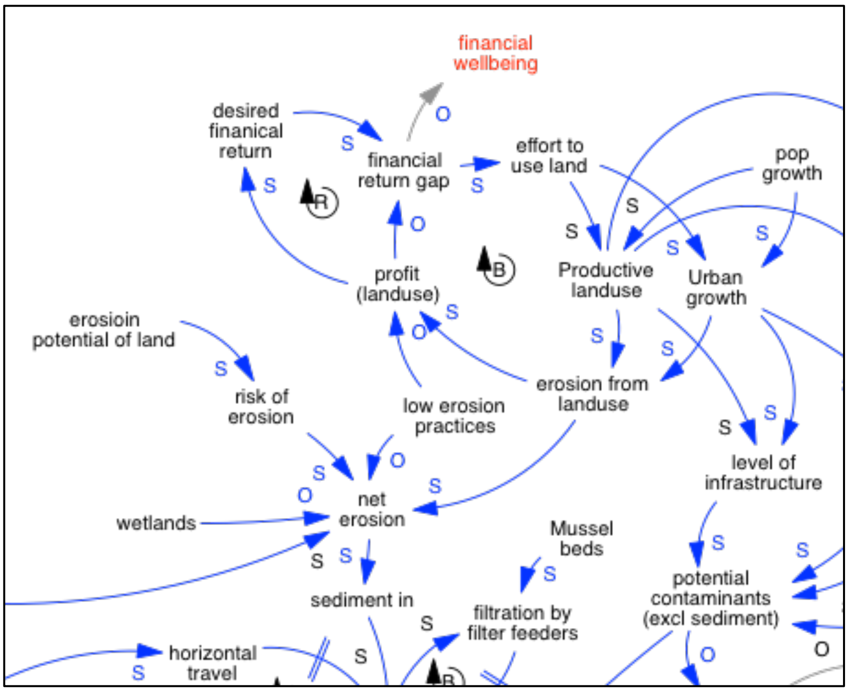
The factor of *Sea floor surface binding (algae)* denotes the algae that feed on *organic* matter and sunlight. They help bind the surface of the sediment on the seabed together, thus reducing *inorganic near-bottom turbidity*. These algae (and thus this binding) is inhibited by the amount of inorganic turbidity and the extent to which that is resuspended through bottom disturbance.

Resuspension (through bottom disturbance) is affected by the human activities of trawling and dredging, as well as the natural currents that are created by tides and wind/waves. While tides operate to a regular cycle, wind and waves are influenced by storm events, which may be increasingly impacted by climate change.

All loops identified between these factors were reinforcing, showing that more or less of none activity would have cumulative impacts on the other factors, resulting in the trend of increasing inorganic turbidity being reinforced. The key factor that balanced this out was the level of accumulated fine sediment, and this was balanced out by the very slow-moving forces of *horizontal travel* and *filtration by filter feeders*.

Horizontal travel is the process of currents gradually moving the fine sediment further offshore into deeper ocean waters in the Cook Strait. *Filtration by filter feeders* describes the process of filter feeders ingesting fine inorganic sediment as a by-product of their feeding process, then excreting it as faeces or pseudo-faeces. This binds that fine sediment into something that settles out of the water column, reducing the amount of accumulated fine sediment and not allowing it to be resuspended. Both of these natural processes occur at a very slow rate and are denoted with delay marks on the arrows. The amount of filtration by filter feeders is related to the number of filter-feeding shellfish there are. In this map (for simplicity) mussel beds have been noted, but others could also be added.

These structures indicate that if there is a large amount of accumulated sediment and bottom disturbance was eliminated, the slow rate of 3D structure regeneration, horizontal travel and filtration by filter feeders would take a very long time to balance out the level of accumulated sediment and turbidity.



The top left of the system map outlines a range of land-based factors that influence the amount of sediment that flows into the Golden and Tasman Bays (left).

Primarily this comes from *net erosion,* broadly determined as the amount of *erosion from landuse* that occurs, minus things that *reduce* erosion (such as sediment captured in *wetlands* and *low erosion practices*). Net erosion is also influenced by the *risk of erosion*, which is related to the type of land it is geologically (*erosion potential of land*).

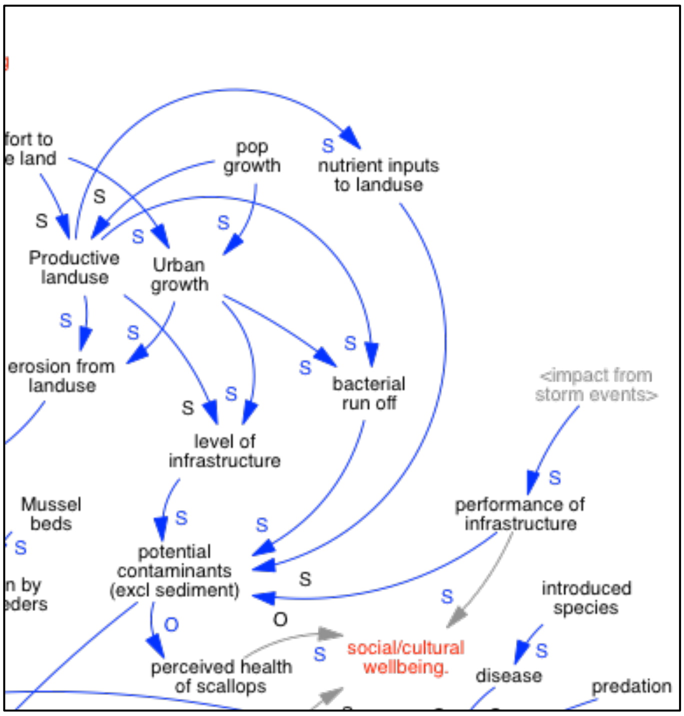
Erosion from landuse is part of **two balancing loops** involving productive land use (of all kinds) and urban growth – articulated to capture the times when erosion from landuse is a higher risk. Erosion of some kind was accepted as a by-product of these two types of landuse (excluding low-erosion practices which may impact this).

Landuse of all kinds were described as being linked to some kind of profit desire – otherwise little would occur. When profit is realised this reduces the gap between *desired* financial return and *actual* financial return (a similar structure to the fishing effort loops). The lower the gap (i.e. the closer people are to realising the returns they want), the lower the continued effort to use the land, the lower the pressure on productive landuse and urban growth, and the lower the erosion from these activities. In turn this will also return lower profit, so if the desired financial return is consistent, these influences will then act in the opposite direction – encouraging landuse and, as a consequence, erosion. Productive landuse and urban growth are also influenced by population growth.

At the same (and again similarly to the fishing loops), an increased profit will increase the desired financial return, which in turn increases the gap between desired and actual financial return. When connected to the balancing loop, these same forces operate as a reinforcing loop where the desired financial returns are continually increased, putting greater pressure on the need to utilise land in some form, resulting in impacts on erosion.

Sediment is considered one type of freshwater contaminant. While these factors relate to the impact of erosion on the level of fine sediment, they also may impact on other types of contaminants.

In addition to the sediment impacts, increases in both types of landuses (productive and urban growth) can also impact bacterial run off into freshwater. Increased productive landuses may also lead to increased nutrient run off to freshwater, due to increased *nutrient inputs to landuse*.



Increasing productive landuse and urban growth will also increase the *level of infrastructure* installed to service these landuses. Examples of this infrastructure are roads and drainage pipes – which increase non-permeable surfaces that facilitate runoff to freshwater bodies. A greater amount of these will increase the likelihood of contaminant runoff.

However, the *performance* of this infrastructure will also have an impact here. It is not just how much of the infrastructure there is, but how well it performs. This could be influenced by age and the level of deterioration, as well as the *design* of infrastructure – for example whether it includes settlement or treatment ponds before release.

The level and performance of infrastructure, and bacterial and nutrient runoff, will all impact the level of *potential contaminants (excluding sediment)* that are discharged. The greater this is, the lower the *perceived health of scallops* will be.

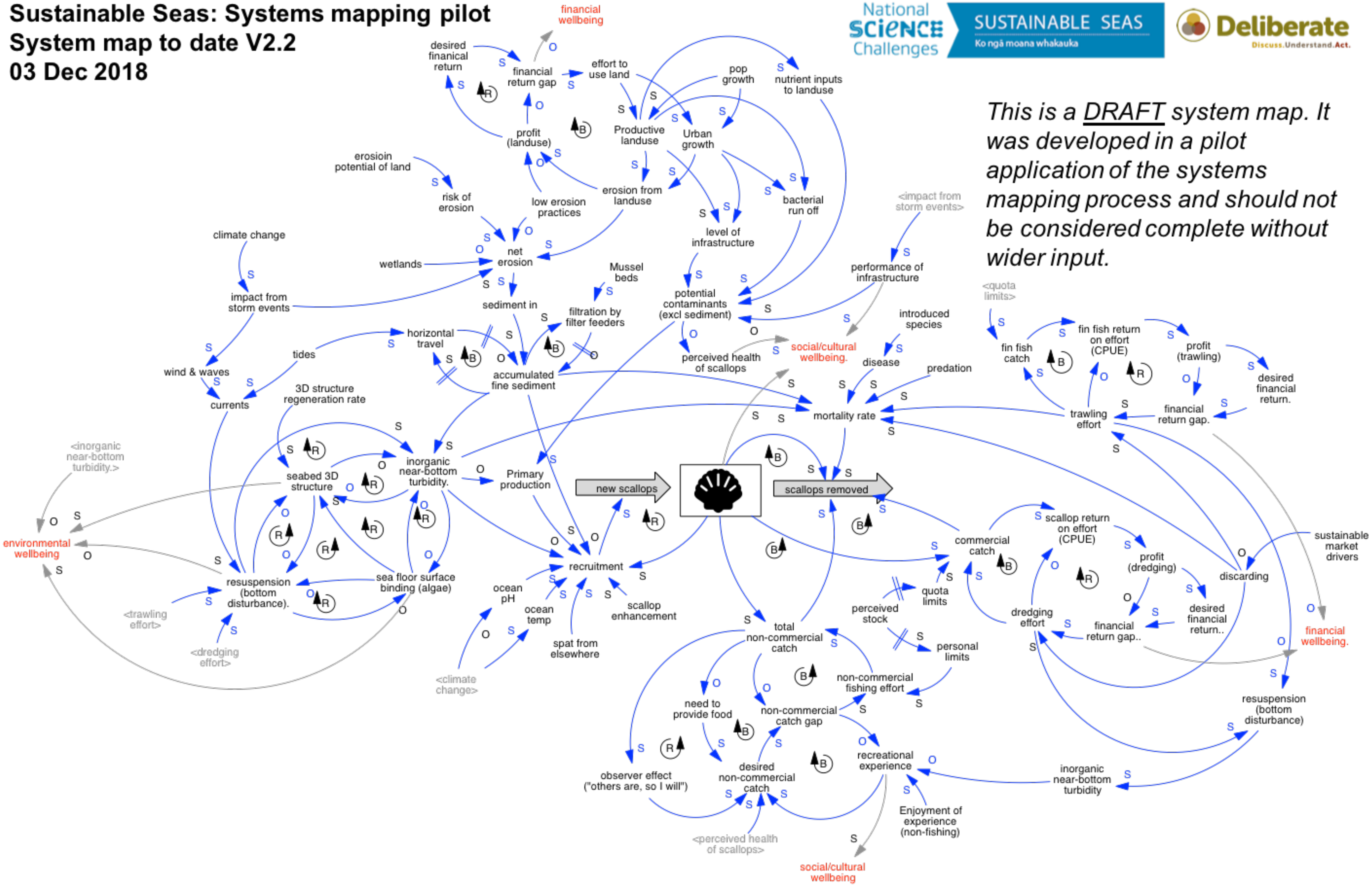
The final factors that are noted on the system map are higher level factors that were articulated as represented general types of ‘wellbeing’: *financial*; *environmental*; and *social/cultural*. These factors are shown in red and indicate how the factors articulated within this system map influence these higher-level factors. It is noted that these were added towards the end of the workshop sessions and were not explored fully. Further discussion and the involvement of a wider range of stakeholders would enable this element of the system map to be strengthened. Yet it is important that the group articulated these connections, as this is a useful example of a systems map helping to articulate wider connections between factors.

It is also noted that social/cultural wellbeing is likely to made up of many factors. These were included as one for reasons of simplicity and in order to save space. They are not equated as the same thing.

Sustainable Seas: Systems mapping pilot
System map to date V2.2
03 Dec 2018

National Science Challenges | SUSTAINABLE SEAS Ko ngā moana whakauka | Deliberate Discuss.Understand.Act.

This is a DRAFT system map. It was developed in a pilot application of the systems mapping process and should not be considered complete without wider input.



	Factor	Description
1	Scallops	Indicated by the square with the scallop shell in the middle. This represents the total amount of scallops in the Bay. During discussions there was some confusion as to exactly when a *new scallop* entered the population of scallops. For example: when it successfully settled on the seabed; when it was able to reproduce; when it reached harvestable size. For clarity this should be agreed and clearly articulated in any future evolutions of this map.
2	New scallops	Indicated by the grey arrow pointing *into* the square of scallops. This represents *new scallops* that are created and enter into the scallop population and covers the various ways that the scallop population *increases*. This is intended to capture a range of steps within the life-cycle of a scallop – from spat to larvae to baby scallop dropping to the seabed. For the purposes of this exercise these various life stages were less important as the system mapping was interested in aggregate factors. Defining exactly when a scallop is deemed to move from this arrow to the square representing the scallop population would be useful for any future evolutions of this map. (see comment sunder *Scallops*)
3	Scallops removed	Indicated by the grey arrow pointing *out of* the square of scallops. This represents any *scallops removed* from the scallop population and covers the various ways that the scallop population *decreases*.
4	Recruitment	This is an aggregated factor that includes all early life stages of a scallop – from spat to larvae to baby scallops dropping to the seabed.
5	Scallop enhancement	The human act of enhancing the scallop population through some kind of intervention in the early life stages. For example: spat catchers that help gather spat over places where humans want them to drop and settle; Or the ‘seeding’ of a scallop population with scallops from elsewhere.
6	Spat from elsewhere	This represents the level of spat that floats into the TBGB area from outside. Levels of spat produced locally are assumed to be low, as the population is so low. However, the levels of spat in the water column are considered high and much of this is believed to circulate into the TBGB area from outside. It is not known where this comes from.
7	Ocean temp	The average temperature of the ocean.
8	Ocean pH	The average pH level of the ocean.
9	Primary production	The filter-feeding potential of the water column based on the level of organic matter and nutrients that are contained within it. This is reduced with higher concentrations of non-organic matter.

10	Accumulated find sediment	The level of fine sediment that is accumulated on the seabed and is available to interact with the water column via ocean currents. Specifically fine sediments as this is most easily able to be resuspended into the water column. There was some confusion during discussion as to exactly whether this meant the depth of sediment on the seabed (which would continually be accumulating and), or whether it was the depth of the layer of fine sediment available to interact with the water column. The facilitator thought that it was the latter – this should be clarified in any future evolution of this map.
11	Horizontal travel	The natural process whereby fine sediment is gradually moved further off shore and into deeper waters by the process of tide movement.
12	Filtration by filter feeders	The process of filter feeders filtering the water in order to consume the nutrients and organic matter contained in it. A by-product of this is that inorganic matter (i.e. fine sediment) is not consumed but bound up by the filter feeder as faeces or pseudo-faeces.
13	Mussel beds	The amount of mussel beds in the TBGB area.
14	Sediment in	The amount of sediment coming into the TBGB area as runoff from the land.
15	Inorganic near-bottom turbidity	The turbidity (cloudiness) created by the resuspension of fine inorganic matter near the seabed. This results in a murky layer at the seabed.
16	Sea floor surface binding (algae)	The initial binding of fine sediments on the seabed by algae that are growing on the seabed. This helps to form a very fine initial crust on the sediment at the seabed. This can be the initial step for further structure to form (see seabed 3D structure)
17	Seabed 3D structure	Solid 3D structure on the seabed. This is created via a range of processes and may include rocks, shells, reefs of shellfish and solid matter excreted from filter feeders.
18	3D structure regeneration rate	The natural rate at which 3D structure will regenerate on the seabed, without disruption by bottom disturbance.
19	Resuspension (bottom disturbance)	The disturbance of the seabed leading to the resuspension of sediments, particularly fine sediment.
20	Currents	The movement of water through the water column by natural currents.
21	Tides	The tidal movement of water in the water column.
22	Wind & waves	The process of wind & waves. This is of interest because these impact on the currents in the water column.
23	Impact from storm events	The various impact that storm events have on the environment. Given the frequency and intensity of storm events is more complicated, it is the *impact from* these that is the focus here.
24	Climate change	The change in regular climate patterns that is currently being experienced and is forecast to continue into the future.
25	Net erosion	The net level of erosion that occurs from land and makes its way into freshwater bodies. This is a function of the total gross erosion minus any erosion that is captured/prevented by assorted human practices or natural processes such as wetlands.

26	Wetlands	The quantity of wetlands that exist on the land.
27	Erosion potential of land	The natural erosive potential of land. This is a combination of things such as the geology and profile of land.
28	Risk of erosion	The risk of land eroding, taking into human as well as natural factors.
29	Erosion from landuse	This is an aggregate factor to account for the erosion that occurs from landuse that is assumed to occur when land is used either for productive purposes or to expand urban areas. While this may occur more significantly when landuse type is *changed* (e.g. converted from pasture to orchards), it is not considered that erosion *only* occurs at a time of landuse conversion. For example, plantation forestry may remain as the same landuse for many years yet will result in some erosion every time harvesting occurs. For simplicity, the focus of this factor is the erosion from various landuses, whether it is the same landuse or a conversion of landuse.
30	Productive landuse	Land that is modified and used productively for human benefit. This includes all types of landuse and it was not considered necessary to consider different types of landuse at this aggregate level. The exception in urban growth (see below).
31	Urban growth	Urban areas were considered by the group to be fairly static in terms of erosion potential for the purposes of this discussion – once an area was urban in form it tended to stay that way for generations. However, when urban areas are expanded, this is when erosion can and does happen. This factor does not suggest that erosion from urban growth is significant or unmanaged, simply that it does occur – even if only within permitted limits. See also low erosion practices.
32	Low erosion practices	Various management practices across a variety of landuses that help to reduce the potential and impact of actual erosion. Different landuses and practices were not necessary for insight at this aggregate level of the map.
33	Population growth	The growth of population through natural increase and migration. This is considered a driver of greater urban growth and productive landuse.
34	Effort to use land	Similar to fishing effort, this factor is an aggregate factor that captures the effort that is put in to using land, either for productive purposes of urban growth.
35	Desired financial return	The desired financial return from a particular type of activity. This factor is the same factor used in the landuse and fishing loops in the map. This reflects the fact that financial return drivers are likely to be common across society and even compete. For example, an investor may have only one desired level of return but could choose to invest in fishing *or* landuse activities.
36	Financial return gap	The gap between a *desired* (target) level of financial return and the *actual* financial return.[3] This factor is the same factor used in the landuse and fishing loops in the map.

[3] 'Gaps' are an important concept in System Thinking/System Dynamics. The difference between a desired and actual level of something can be a major contributor to the *strength* of that loop. For example, when a gap is larger it may lead to a greater level of effort (either conscious or not) to

37	Profit (landuse)	Profit gained from a particular type of landuse.
38	Nutrient inputs to landuse	An aggregate factor representing the various nutrients that may be added and an input to different landuses.
39	Bacterial runoff	Runoff of bacteria from different landuse. This was predominantly assumed to be *E. coli* but may include other types of bacteria.
40	Level of infrastructure	The *amount* of infrastructure that aids in the transport of water 9and therefore nutrients and bacteria) to freshwater bodies. For example, roads, drainage and water treatment facilities.
41	Performance of infrastructure	The *level of performance* of infrastructure that aids in the transport of water 9and therefore nutrients and bacteria) to freshwater bodies. For example, older drainage systems may include less opportunities for water retention and settlement. Differing water treatment facilities may achieve different levels of treatment. These differences may be *design* or *age* related.
42	Potential contaminants (excluding sediment)	The level of potential contaminants (excluding sediment) that reach the ocean. 'Contaminants' refers to a common set of things in freshwater that are undesirable above a certain level and are actively managed by resource managers. While sediment is one of these, it is accounted for with the factor *Sediment in*.
43	Perceived health of scallops	The level of health that scallops in TBGB are perceived to have. The term 'perceived' is deliberately used as there are differing social/cultural perceptions on what is considered 'healthy' or not.
44	Fin fish catch	The quantity of fin fish caught by the fin fish fishery.
45	Fin fish return on effort (CPUE)	The Catch per Unit Effort (CPUE) achieved for the fin fish fishery. This is a standardised way of measuring the amount of effort required to catch an amount of fish. It is a common measure in the industry and is an indication on the return on investment of fishing.
46	Profit (trawling)	The profit returned from fin fish trawling activities.
47	Trawling effort	The amount of effort expended in trawling for fin fish.
48	Commercial catch	The quantity of scallops caught by the scallop fishery.
49	Scallop return on effort (CPUE)	The Catch per Unit Effort (CPUE) achieved for the scallop fishery. This is a standardised way of measuring the amount of effort required to catch an amount of scallops. It is a common measure in the industry and is an indication on the return on investment of fishing.
50	Profit (dredging)	The profit returned from scallop dredging activities.
51	Dredging effort	The amount of effort expended in dredging for scallops.

undertake some kind of activity and reduce that gap. When a gap is smaller there is less strength in the same effort. Strength of effort is a major influence on the *dominance* of various loops and factors within them and demonstrates how this *dominance can change over time*.

52	Discarding	The act of discarding some of a catch (fin fish or scallops) whilst still at sea. This may be because the catch is undersize of the fisher may have reached their quota. This factor does not note the legality of this activity, simply that is can occur.
53	Sustainable market drivers	A factor that aggregates a range of potential drivers from various markets. This indicates that the sustainability of a fishery would in part be judged by the level of discard that occurs.
54	Perceived stock	The perceived stock of scallops. This is based on surveys undertaken by the Ministry for Primary Industries (MPI) which are used to estimate scallop stocks and inform commercial and non-commercial limits.
55	Quota limits	A variety of regulatory mechanisms that limit how much scallops the commercial fishery can catch.
56	Personal limits	Regulatory mechanisms that limit how much scallops that non-commercial fishers can catch.
57	Total non-commercial catch	The total non-commercial catch of scallops. This includes a range of mechanisms within the Quota Management System (QMS) but the details of these were not considered necessary at this level of aggregation.
58	Non-commercial fishing effort	The amount of effort expended by non-commercial fishers on gathering scallops.
59	Desired non-commercial catch	The desired level of non-commercial scallops sought. This will vary for different people and is an aggregate total for the quantity of scallops and the frequency at which they are caught.
60	Need to provide food	The driver of needing to provide food for yourself and/or one’s family.
61	Observer effect (“others are, so I will”)	The driver of a network impact that seeing other people collecting scallops will have on your desire to collect scallops.
62	Recreational experience	The aggregate recreational experience of scalloping. Catching scallops only accounts for part of this.
63	Enjoyment of experience (non-fishing)	An aggregate factor that accounts for the enjoyment that people get from the act of scalloping, that is not dependent on the number of scallops caught.
64	Financial wellbeing	An aggregate factor to capture the level of financial wellbeing enjoyed by an individual or a group.
65	Environmental wellbeing	An aggregate factor to capture the level of environmental wellbeing enjoyed by an individual or a group.
66	Social/cultural wellbeing	An aggregate factor to capture the level of social/cultural wellbeing enjoyed by an individual or a group.

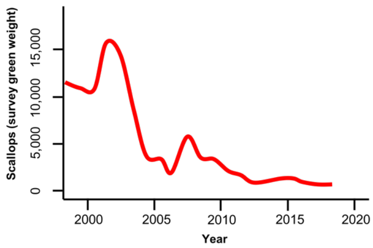
Appendix 3 Pre-test/post-test survey to test mental model change

Systems mapping pilot - Pre-workshop 1 questions

(print this page out, fill in the answers and bring with you to workshop 1)

Name:	

The stylised graph to the right shows the amount of scallops (as measured by surveyed green weight) over the last 20 years.



Pre-workshop question:

What are the important factors that influence(d) the decline in the amount of scallops in the Tasman & Golden Bay areas?

(write these in the box below and bring to workshop 1)

How regularly do you feel you discuss the issue of the declined amount of scallops in the Golden/Tasman Bay areas? *(tick one)*

Every day	At least once a week	At least once a fortnight	At least once a month	Once every few months	Only occasionally	Never
☐	☐	☐	☐	☐	☐	☐

Appendix 4 Post-pilot survey about participants experience of the workshops

Research Project: CP 2.1

Workshop no. 3 **Feedback Form for Participants**

Please note: Completing and submitting the feedback form is implied as consent. The information provided in this survey will be non-traceable to individuals.

Instructions: Please circle the number that best represents how you feel about the statement on a scale from 1 (Strongly Agree) to 6 (Strongly Disagree).

Statement	Strongly Agree					Strongly Disagree
1. I believe my knowledge of the problem before the workshop was good.	1	2	3	4	5	6
2. I have gained new knowledge through my involvement in these workshops over the last few weeks	1	2	3	4	5	6
What is the new knowledge you have gained?						
3. I found the concept of systems maps easy to understand	1	2	3	4	5	6
4. I found the *process* of creating a systems map easy to follow	1	2	3	4	5	6
5. I think we (the participants) had sufficient opportunity to discuss the key issues through-out the process	1	2	3	4	5	6
6. This process helped me better understand the perspectives of other people in the room	1	2	3	4	5	6
7. I think this process has helped us to consider new factors that that we hadn't previously thought of that influence scallops in the Bays	1	2	3	4	5	6
8. Considering the system holistically will help support workable solutions/interventions	1	2	3	4	5	6
9. Acknowledging that this is a pilot process, I am comfortable with the system map we have generated	1	2	3	4	5	6

Statement	Strongly Agree					Strongly Disagree
10. I find it easy to make sense of the final systems map	1	2	3	4	5	6
11. I feel that my contributions to this process (i.e. knowledge, ideas and questions) were valued	1	2	3	4	5	6
12. I can see my contributions to the discussions in the system map	1	2	3	4	5	6
13. This group has worked well together collaboratively to develop the map	1	2	3	4	5	6
14. I would be willing to participate further in development of this map	1	2	3	4	5	6
15. Having experienced this process creating a systems map, I would invest into a similar process in another setting	1	2	3	4	5	6
Why is this?						
16. I would recommend to others to participate if the opportunity arose to be involved in a similar process	1	2	3	4	5	6
17. I think this approach would be useful in a real-world planning decision	1	2	3	4	5	6
Why is this?						
Thank you for your feedback! **Any other comments?:**						

18. Something that worked well in the process was

19. Something that I would change about the process was

20. Something that I have found challenging regarding the process was

If you wish to make further comments on this workshop, please contact Justin Connolly justin.connolly@deliberate.co.nz

Appendix 5 Copy of previous report

This appendix contains a copy of the report carried out before this pilot was run. This assessed possible conceptual applications of Systems Mapping on the Sustainable Seas project. That report was titled *Conceptual options for incorporating Systems Thinking into Project CP2.1 of the Sustainable Seas National Science Challenge*.

The full citation is below:

Deliberate. (2018). *Conceptual options for incorporating Systems Thinking into Project CP2.1 of the Sustainable Seas National Science Challenge*. Hamilton, New Zealand: Justin Connolly.

Note: References to costs have been removed from this report due to commercial sensitivity.

Deliberate

Discuss.Understand.Act.

NIWA

(The 'Sustainable Seas' National Science Challenge)

Conceptual options for incorporating Systems Thinking into Project CP2.1 of the Sustainable Seas National Science Challenge

September 2018

Report by:

Justin Connolly Director, Deliberate

Discuss. Understand. Act.

Author

Justin Connolly

Director, Deliberate

September 2018

Acknowledgements

The author gratefully acknowledges Paula Blackett, Rochelle Selby-Neal and Jim Sinner for their existing project knowledge and advice in in constructing this document. Their review comments have been invaluable.

Version

Date	Comments	Authorised by
17 September 2018	Report finalised after reviewer comments incorporated.	Justin Connolly Director, Deliberate
4 March 2019	*The financial estimates for each option listed in the report have been removed, as they are considered commercially sensitive. This is so this report can be included in the appendices of the report of the pilot work carried out in late 2018.*	*Justin Connolly Director, Deliberate*

Disclaimer

The author has prepared this report for the sole use of the client and for the intended purposes stated between both parties. Others may not rely upon this report without the written agreement of the author and the client. No part of this report may be copied or duplicated without the express permission of the author or the client.

The author has exercised due and customary care in compiling this report. No other warranty, express or implied is made in relation to the conduct of the author or the content of this report. Therefore, the author does not assume any liability for any loss resulting from errors, omissions or misrepresentations made by others.

Any recommendations or opinions or findings stated in this report are based on the circumstances and facts at the time the research was conducted. Any changes in the circumstances and facts on which the report is based may affect the findings and recommendations presented.

Table of contents

1 Introduction 1

2 What is systems thinking? 3

2.1 Balancing and reinforcing loops. 3

2.2 Overview of a systems mapping process 4

3 A history of stakeholder involvement in system thinking 5

4 The purpose of CP2.1 – how to assess systems thinking 6

5 Three options for consideration 7

5.1 Context – starting systems mapping part-way through an existing research programme 7

5.2 Option 1: Developing a system map with Managed Seas modelling work – high level of coordination 7

5.3 Option 2: Developing a system map with Managed Seas modelling work – low level of coordination 8

5.4 Option 3: ‘Piloting’ system mapping independently of Managed Seas modelling work, for further use in tranche 2 9

6 Outputs, process and resources 10

6.1 Conceptual outputs 10

6.2 Process 13

6.3 Resources 15

7 Assessing the options and recommendation 22

7.1 Assessing the options 22

7.2 Recommendation 27

8 Additional considerations for publication of results 28

9 Conclusion 28

10 References 29

1 Introduction

In August 2018 Justin Connolly from Deliberate was commissioned to explore the potential application of systems thinking on the CP2.1 project of the 'Sustainable Seas' National Science Challenge. The CP2.1 project is seeking to research and foster Ecosystem Based Management (EBM) in the Tasman Bay & Golden Bay area (TBGB) area, with a view to this informing how policy development may be approached using EBM in the future. At that time the CP2.1 project was planning its programme of work for the balance of 'Phase 1' of the National Science Challenge – through to around June 2019.

EBM is defined as a holistic and inclusive way to manage marine environments and the competing uses for, and demands on, the ways New Zealanders value them. Sustainable Seas is researching how the possible application of EBM may be approached. The practical issue that the EBM approach will be anchored around is the declining (or declined) sea bed health in the TBGB area. Understanding the wider system (at a synthesised level) of factors influencing sea bed health in the TBGB area is beneficial to an exploration of the opportunity to apply EBM.

Systems thinking recognises that the entire world is an inherently inter-connected place. Any one person's understanding of such a system is based on the mental model they hold of how that system works. Peoples mental models are informed by varying things including scientific truths and personal experience. Systems thinking acknowledges that it is unlikely that an entire system will ever be fully 'known', therefore it seeks to build a synthesised understanding of a wider system by aligning the 'mental models' of those most familiar with it and mapping out the interconnections. This increases the shared understanding of a system across a range of interested parties. Further, it provides insight into influences into that system that may not have obvious.

Deliberate has been invited to provide a perspective on the use of systems thinking with Sustainable Seas for several reasons. First, Deliberate has successfully applied systems thinking on another Science Challenge with project staff that are involved with Sustainable Seas. The application of systems thinking on this other Science Challenge has helped to synthesise a range of complex data and stakeholder[1] perspectives into a coordinated system map, which most stakeholders found usefully represented their views and helped synthesise those with other perspectives. Second, given the success of the approach elsewhere, systems thinking and the type of systems map that it can generate, is seen as a potentially useful tool for the Ecosystem Based Management (EBM) approach being researched in Sustainable Seas.

Additionally, the opportunity to use a systems map focusing on factors that influence the health of the sea bed, is a potential complementary tool to the varying detailed technical studies underway within the Science Challenge. It is anticipated that such a systems map will provide an opportunity to explore, at a high level, how all of these various studies 'fit together' across

[1] In this report the term 'stakeholder' is used to refer to any person or entity who hold an interest, stake, or responsibility in the management of the resource of TBGB.

the Science Challenge. That is, not only might the system map provide a map of the wider system, but also a useful 'map' of the various technical studies/tools being undertaken/developed and how they all fit together. It is expected that this approach will help to identify opportunities to refine these studies and/or further explore how they fit together and whether any 'science gaps' remain, prior to tranche 2 of the National Science Challenge commencing in July 2019.

In conjunction with Rochelle Selby-Neal, Justin met with some of the CP2.1 project team (in August 2018) to learn about the intention of the project, the programme of studies in general and several key projects that were seen as integrating with a systems thinking approach. He was then involved with 2 days of general planning for CP2.1 staff, where he discussed what value system thinking may provide and to generate options for how this approach may be incorporated in conjunction with overall project planning.

In the two-day general planning meeting above, the below were articulated as a summary of the project purposes for CP2.1:

- Trialling participatory practices and science tools.
- Building shared understandings of the 'system' (ecosystem)
- Building new understanding of EBM and what this means for the possibilities of implementing EBM.
- Fostering a community that is ready, willing and able to apply/trial EBM.

The bulk of this report provides some conceptual options for incorporating systems thinking into the CP2.1 project in line with the above purposes.

This report originally focused on developing two conceptual options to consider. However, during drafting (approx. 2 weeks after meeting with the project team) it was indicated that resources may be constrained to 2-3 workshops only. As these resource constraints are unlikely to be sufficient for the two initial options, a third option is scoped. This outlines how the approach may be 'piloted' with these constrained resources.

Section 2 of this report provides an introduction to systems thinking while section 3 provides an overview of how stakeholder involvement has been used within it. Section 4 outlines what CP2.1 is trying to achieve, while sections 5 and 6 outline the conceptual options and the outputs, process and resources for each. As per the commission, these are provided at a conceptual level; detailed planning will be required for any option that may be developed further. Section 7 assesses the options and provides a recommendation. Section 8 provides insights from the systems thinking literature that will be useful is seeking publication of results from this research. Section 9 provides a summary and conclusion.

2 What is systems thinking?

The world that we live in is a highly interconnected place, with many variables interacting in different relationships of cause and effect. Environmental policy development usually seeks to respond to or correct undesirable behaviour or patterns presenting in our natural environment. It seeks to influence these causes in order to alter or improve the desired behaviour.

Systems thinking is a conceptual framework and set of tools that have been developed to help make these patterns of interconnectedness clearer (Senge, 2006)[2]. They help us understand how the *structure* of a set of various interacting factors influences the *behaviour* of the variable(s) of interest. This helps us better understand *which parts* of a system are having the most influence on our behaviour of interest and allow us to identify areas of leverage to influence this.

'Systems thinking' is a name often applied or interchanged to the 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. The term systems thinking as it is used in this report refers to the concepts articulated by the discipline of System Dynamics (Sterman, 2000).

2.1 Balancing and reinforcing loops.

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, 2006).

In a *reinforcing feedback loop*, the influence provided by an initial factor to another will transfer through the loop via one or more factors 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. For example, if a variable of interest is *increased*, when that influence flows through the feedback loop it will present as an *increasing influence* on that original variable.

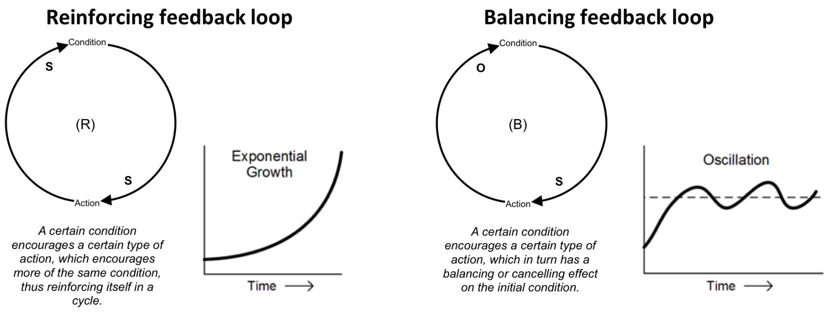
In a *balancing feedback loop*, the influence provided by an initial factor to another will transfer through the loop via one or more factors and influence back on the originating factor in the *opposite* direction. This has the effect of *balancing out* the direction of the original influence. For example, if a variable of interest is *increased*, when that influence flows through the feedback loop it will present as a *decreasing influence* on that original variable.

The two types of feedback loop and their characteristic patterns of behaviour are shown in Figure 1.

---

[2] 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.

Figure 1. The two types of feedback loops and their characteristic patterns of behaviour



Adapted from Senge (1990) and Ford (2010)

Feedback loops can be made up of more than two variables and can be mapped together to form a system map (also called a *causal loop diagram (CLD)*). The way that these interact in a wider system helps provide insight into the what is causing the *behaviour within the system*.

2.2 Overview of a systems mapping process

Having established feedback loops as the basic building blocks of systems thinking, this section outlines the core of a systems mapping process.

Systems thinking recognises that the entire world is an inherently inter-connected place. While it may be tempting to attempt to apply the tools of systems thinking (feedback loops, system maps) to try and map out the entire world at once, in reality we need to focus our cognitive abilities on an issue of interest so that we are not overwhelmed. Any insights gained can then be of practical use.

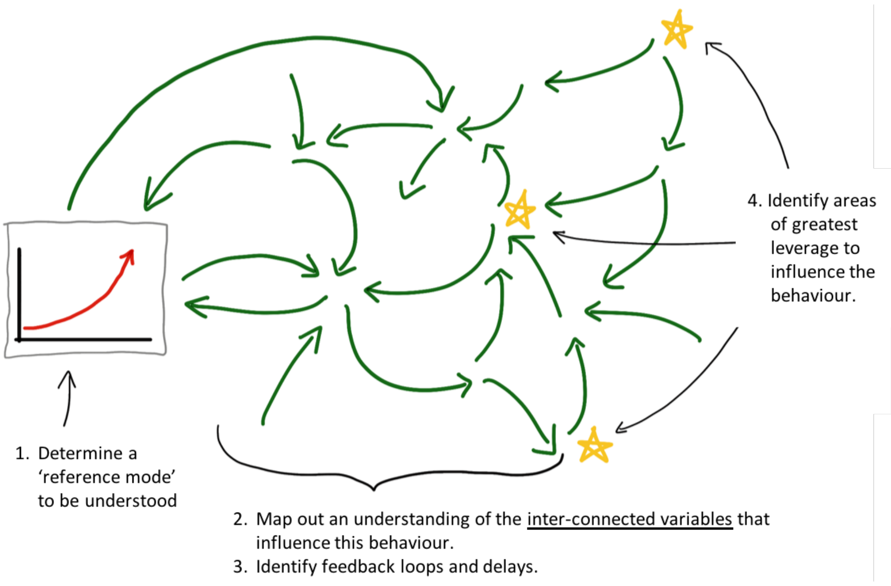
Therefore, systems mapping exercises are best directed by seeking to understand a problematic trend in some kind of variable of interest. This is best represented by a behaviour over time graph (a.k.a. a 'reference mode') rather than a static level of some kind of variable of interest. For example, "a declining level of….", or "an increasing concentration of…", or "a fluctuating level of [X], despite consistent levels of [Y]". This is important because a key objective of systems thinking is generating a *broad* understanding of how various parts of a system interact to create the *dynamic* behaviour of interest.

An overview of the systems mapping process is as follows:

1. Determine/agree a reference mode ('behaviour over time' graph).
2. Working back from this point (as individuals or as a group in workshops) build up an understanding of the immediate influences of this behaviour, then the influences on those influences, etc.
3. Identify feedback loops and delays in this system structure. This builds a deeper understanding of the *dynamics* within the system.
4. Use this understanding to identify potential *areas of leverage* within the system – where in the system can you intervene with the most leverage to improve the undesirable behaviour?

A conceptual example of what a systems map may look like is shown in Figure 2.

Figure 2. ***Conceptual example of a system map***



3 A history of stakeholder involvement in system thinking

The previous section provided an overview of the systems thinking approach. This section describes the history of stakeholder involvement in the development of systems maps.

Systems thinking theory itself can be applied without the involvement of stakeholders. Yet there is a strong history of stakeholder involvement in the development of systems dynamics models since the foundation of the discipline (Forrester, 1961; 1969). This is because one of the intentions of systems thinking has always been to help groups develop an *understanding* of how a complex system may *behave over time*. It has done this by working with groups to explore and align their *mental models*, or their internalised understandings of how the world works (Sterman, 2000).

Consequently, a tradition of stakeholder participation has developed within System Dynamics (Vennix, 1996; van den Belt, 2004; Hovmand et. al, 2012). This has proven to be useful as a problem structuring method and to improve groups' shared understanding of a problem (Rouwette et. al, 2002; Scott et. al, 2016). Such participatory approaches also have a track record of use with New Zealand environmental issues (van den Belt et. al, 2013; Connolly, 2017).

Given the purpose of the CP2.1 project to build a shared understanding of the system influencing seabed health in TBGB, the conceptual options laid out in this report are based on stakeholder involvement in the systems mapping process. In accordance with the systems thinking/System Dynamics literature, this is intended to make shared mental models explicit and increase shared understanding. It is noted that there is a concurrent stream of work on participatory processes on the Sustainable Seas Science Challenge. While this is considered complementary and there are likely to be synergies in how both may inform of work with each other, exactly how that may occur is beyond the scope of this report and may be explored in detailed planning if the system mapping approach is progressed.

4 The purpose of CP2.1 – how to assess systems thinking

Previous sections outlined a summary of the systems thinking approach and how it is intended to increase shared understanding of a system (sections 2 & 3). The purposes of the CP2.1 project was also noted in section 1, yet are rearticulated here with the intention of providing criteria against which options provided in this report may be assessed.

Table 1 outlines the purpose or CP2.1 and offers commentary as to how systems thinking is anticipated to contribute to these in general. These will be revisited later in the document and assessed against each option.

Table 1. The purpose of CP2.1 as criteria for assessing different systems mapping options

CP2.1 Purpose	Perceived benefit of system thinking
Trialling participatory practices and science tools.	Offers an opportunity to link with participatory processes work on Sustainable Seas.
Building shared understandings of the 'system' (ecosystem)	Make implicit mental models of contributors explicit and increase areas of shared understanding. The process of participants sharing their understanding of an issue helps them understand where their view sits alongside other's views. Helps synthesise peoples understanding of various strands of the science being undertaken. May identify gaps in the existing science.
Building new understanding of EBM and what this means for the possibilities of implementing EBM.	Identify potential for policy (mis)alignment across agencies Identify key factors for valuation (from those affected by intervention scenarios)
Fostering a community that is ready, willing and able to apply/trial EBM.	Provide catalyst for trialling EBM. Build capacity for engaging with others on an issue in a neutral space.

5 Three options for consideration

The previous sections outlined the background to this report, introduced systems thinking and described the strong history of stakeholder involvement in systems mapping. This section outlines some context relating to beginning a systems mapping exercise part-way through an existing research programme, then outlines three conceptual options for consideration.

The first two options are outlined in response to the original invitation to provide ideas as to how systems thinking might be applied on CP2.1: Option 1 being a theoretical approach and Option 2 being an approach requested by some project members. During the development of the first two options, after meeting with the project team, it was indicated that there were likely to be resource constraints (primarily time and funding) that would have an impact on the systems mapping approach. Therefore, a third option was developed (Option 3) that responds to a specific indication that project resources may only allow 2-3 workshops.

5.1 Context – starting systems mapping part-way through an existing research programme

When initiating a system mapping process, it is usual to begin with a behaviour over time (reference mode) and then identify a wider range of variables influencing that behaviour. Theoretically this would be initiated from a ‘blank slate’. Yet in the reality of applied research the world does not always conform to theoretical ideals, systems mapping therefore is sometimes initiated after other complementary work on a project has already been initiated. This is the situation with the Sustainable Seas National Science Challenge, which has a range of projects that are at varying stages of progress and the systems mapping approach is being explored as a complementary and integrating approach after these have begun. It is partly being investigated as a tool to help integrate the various work already underway and to help people synthesis how various strands of research fit together.

5.2 Option 1: Developing a system map with Managed Seas modelling work – high level of coordination

The objective of the first conceptual option is to develop a system map with a high level of coordination with the Managed Seas modelling work that is being undertaken. This would integrate systems mapping into the wider programme of work resulting in a wider overview of the system contributing to sea bed health in TBGB. It is also expected to provide insight into the areas of that system that are covered by the existing technical studies/tools being undertaken/developed in Managed Seas.

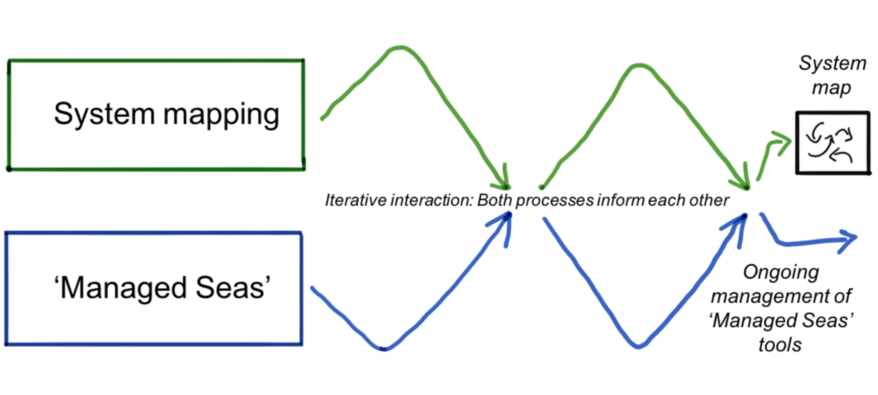
There is a history of scientific work in this geographical area as well as the scientific work already carried out by the Sustainable Seas Science Challenge. This approach recognises that this comprehensive body of knowledge exists and would initially be anchored around mapping an understanding of that scientific knowledge relating to the seabed (effectively a seabed ‘sub-system’) before expanding to the wider system.

This recognises that the systems mapping exercise is a complementary tool to the detailed reductionist scientific studies being undertaken. In this option, Managed Seas scientists and other stakeholders such as iwi, community members and relevant staff from local and central government institutions would be actively involved in systems mapping. Detailed scientific knowledge then informs the synthesised systems understanding, and the systems understanding helps identify gaps or deficiencies in the detailed scientific studies. This option provides the greatest opportunity to increase shared understanding of the influencing factors in the system and an alignment of participants 'mental models' – both scientific staff and stakeholders (this is shown conceptually in Figure 3).

A useful guideline for the number of participants that can practically contribute in a workshop session is 6-12. Fewer than six and the opportunities to share different perspectives is reduced, while more than 12 and participants ability to effectively contribute is reduced. Of course, more than 12 people can be involved with systems mapping, the final number just has an impact on the logistics of how the systems mapping workshops are run – e.g. in series or in one larger workshop with multiple facilitators trained in systems mapping working with different groups. Determining the final profile and numbers of participants is beyond the scope of this report, so only indicative figures can be provided when resources are considered in relation to the process (see section 6).

This option would likely to be the most resource intensive given its involvement of both scientific staff and stakeholders; and its intention to take a holistic view of the entire TBGB area.

Figure 3. Conceptual diagram of Option 1: Developing a system map with a high level of coordination with existing Managed Seas modelling work



5.3 Option 2: Developing a system map with Managed Seas modelling work – low level of coordination

The second option involves the development of a system map by stakeholders, with a low level of coordination with the Managed Seas modelling work. This recognises that while, ideally, system mapping is integrated into the wider programme of work, resource (particularly time) constraints mean that this is unlikely in the timeframe given. It expected to provide some insight into the areas of the system that are covered by the existing technical studies/tools, yet with more of a focus on stakeholders at the expense of those undertaking/developing studies/tools in Managed Seas. This option was requested by some members of the project team.

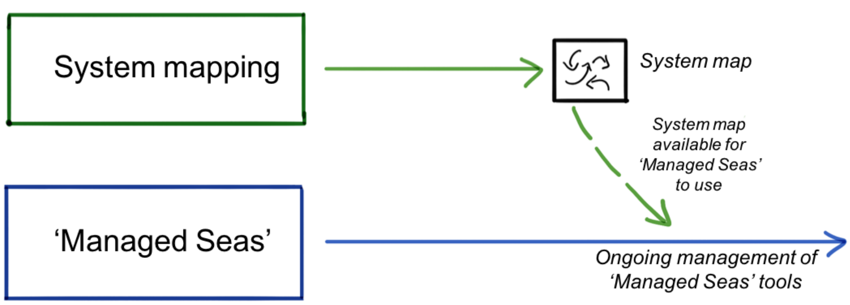
The main difference between the two options is the extent to which a wider range of stakeholders (including scientists) are involved in developing the initial understanding of that sub-system.

This option requires fewer resources, especially time, and it is expected that the systems map remains a complementary tool to the detailed reductionist scientific studies being undertaken. It would still be anchored around building an initial understanding of the seabed ‘sub-system’. However, the detail for this would be provided from more targeted expert opinion and a smaller workshop, rather than a larger workshop mapping exercise. The results of this system mapping exercise would still be available for use by the Managed Seas programme (this is shown conceptually in Figure 4).

However, because there are fewer scientific staff involved, there is an increase in the risk of a mal-alignment of system understanding across various scientific staff and stakeholders. In short, the system map may not be as much use to the Managed Seas programme as if developed in conjunction with them (as in Option 1). Given that one of the key aims of system thinking is to make implicit mental models explicit amongst stakeholders and develop a greater shared understanding of the influences in the system, this option reduces the likelihood of this anticipated outcome.

While less resource intensive than Option 1, this option still requires a significant amount of resource given: its involvement of some scientific staff and a number of stakeholders; and its intention to take a holistic view of the entire TBGB area.

Figure 4. Conceptual diagram of Option 2: Developing a system map with a low level of coordination with existing Managed Seas modelling work



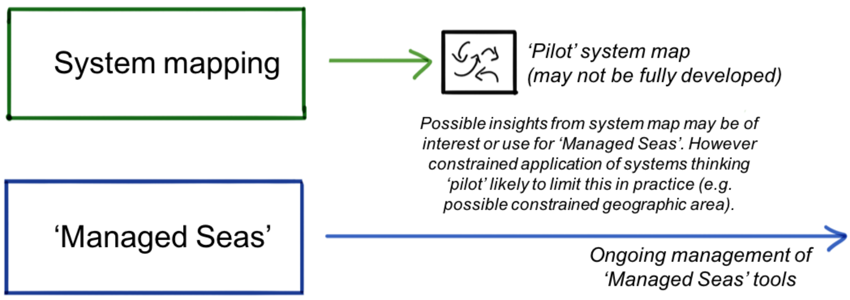
5.4 Option 3: ‘Piloting’ system mapping independently of Managed Seas modelling work, for further use in tranche 2

When originally in development, it was expected that this report would only include the first two options already outlined: Option 1, a conceptual option with a high level of integration with other scientific work being undertaken on the Science Challenge; and Option 2, a conceptual option responding to a specific request that the two streams of modelling (system mapping and the 'Managed Seas' modelling) were not integrated. When writing this report the project team indicated that resources for this work may be significantly constrained. Therefore, this section outlines a third option, Option 3, that responds to a specific constrains of possibly only 2-3 workshops. In this option, it is recommended that the system modelling workshops be limited to a maximum of 12 participants.

Option 3 is not considered an appropriate comprehensive approach to systems mapping for the purposes of decision-making purposes or gaining a full understanding of the system. However, it is considered an appropriate approach to 'pilot' systems mapping in an EBM context. In other words, this is seen as a practical way of 'testing' the usefulness of systems thinking, and system mapping in particular, for enabling EBM. This is shown conceptually in Figure 5.

This recognises that the systems mapping exercise is a complementary tool to the detailed reductionist scientific studies being undertaken. 'Managed Seas' scientists and wider stakeholders are actively involved in systems mapping. Detailed scientific knowledge then informs the synthesised systems understanding, and the systems understanding helps identify gaps or deficiencies in the detailed scientific studies.

Figure 5. Conceptual diagram of Option 3: 'Piloting' systems mapping independently of Managed Seas modelling work



6 Outputs, process and resources

This section outlines conceptual outputs, an outline of the process, and an estimate of resources for each option.

6.1 Conceptual outputs

This section outlines the conceptual outputs (in terms of system maps) that are anticipated from each option.

While the declining health of the sea bed is an appropriate reference mode to explore, how to deal with the concurrency of research has resulted in different suggestions. While one could start with a 'blank slate', given that many technical studies are already at an advanced stage it has been suggested by some project team members that the ecosystem surrounding the sea floor is first mapped out as a 'sub-system'. This sub-system mapping (for options 1 & 2) is likely to be (predominantly) with a range of scientists involved in the other studies. This will identify a range of stressors which are influencing that sub-system, from where the wider system of influences can be mapped out. Yet, the less cross over of participants between building the 'sub-system' and the 'wider' system, the increased risk that this 'sub-system' is only seen to include scientific views, this may limit any shared understanding from an early stage in the process.

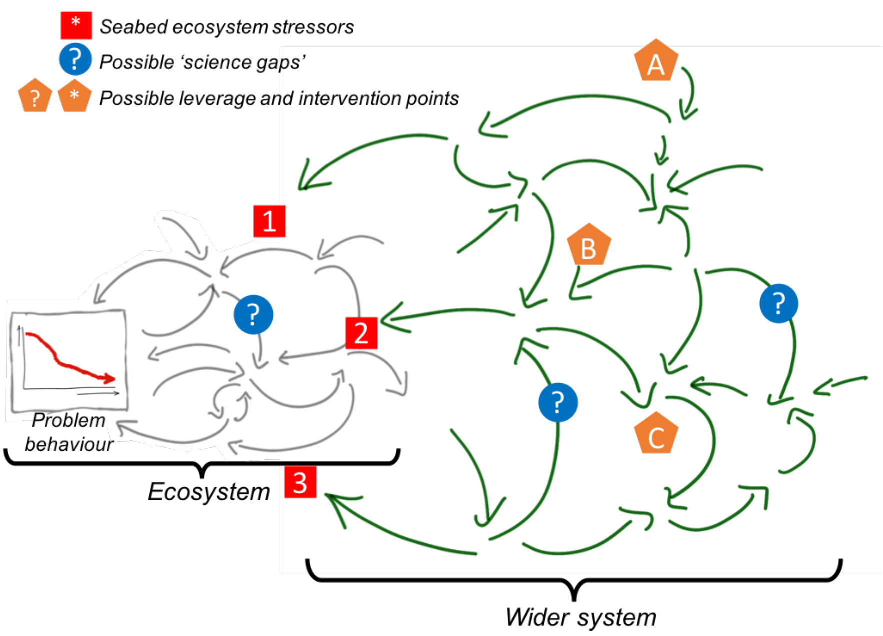
6.1.1 Conceptual output – Options 1 & 2

Both Options 1 & 2 are anchored around first building an understanding of the seabed 'sub-system'. A conceptual diagram of the anticipated output of this systems mapping approach is shown in Figure 6.

Once the wider system has been mapped out from the stressors (1-3 in red), possible 'science gaps' can be identified (question marks in blue). These are parts of the system where this process identifies where there may be a lack of scientific data or understanding, which may in turn help direct some of the scientific analysis occurring in other studies on the Challenge. Further, the systems mapping may also identify leverage points in the system (A-C in orange) where intervention may have a higher chance of influencing the reference mode. This sub-system first approach to system mapping has been assumed for conceptual options 1 & 2 that follow.

As noted earlier, the main difference between the two options is the extent to which a wider range of stakeholders (including scientists) are involved in developing the initial understanding of that sub-system. Option 1 seeks to work with a wide range of scientists and stakeholders throughout, so that stakeholders understanding of the sub-system is informed by discussions with scientists, as well as scientists views of the wider system are informed by stakeholders' views of it. In Option 2 there is a lower level of coordination between the systems mapping exercise and the Managed Seas modelling. Therefore, the sub-system mapping is more focused on scientist input and the wider system more focused on stakeholder input. This may reduce the level of shared understanding between these various participants, which is the main intention of the systems mapping approach.

Figure 6. Diagram of conceptual output – Options 1 & 2

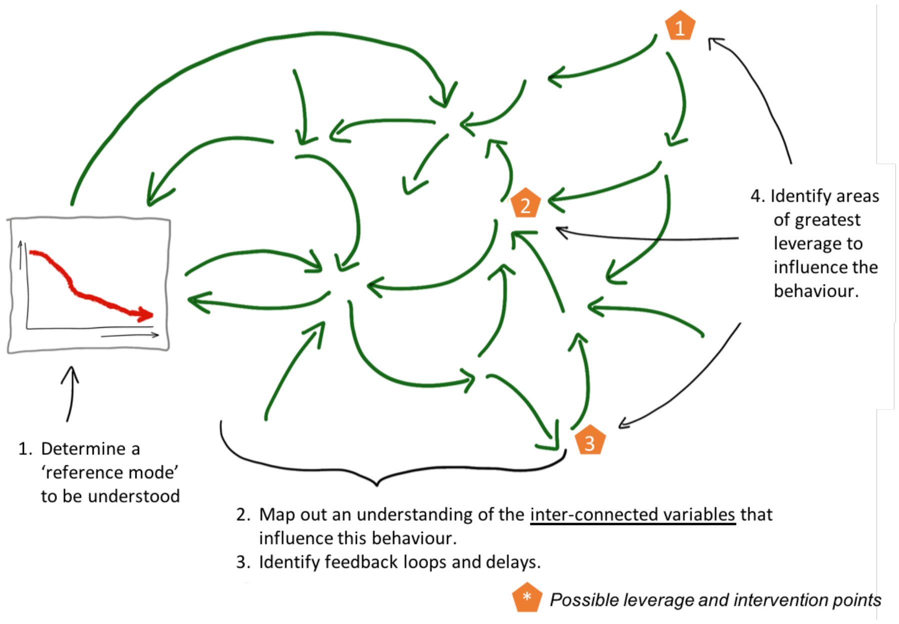


6.1.2 Conceptual output – Option 3

With limited resources, the output from a third option would more closely resemble the conceptual output outlined in Figure 2. Resource constraints would mean that it is not possible to focus on the seabed 'sub-system', so the workshops would focus on generating an aggregated and synthesised understanding of the whole system. A conceptual diagram of this is shown in Figure 7.

Key stressors of seabed health may need to be taken as 'given' by scientific advice for the purpose of this exercise. While this will reduce the shared understanding of participants about this sub-system component from the beginning, it will enable a focus on the full system. It is noted though that resource constraints will mean that this is at a fairly aggregated level.

Figure 7. Conceptual diagram of the output from Option 3



6.2 Process

This section provides a summary of the anticipated processes for each option. These would need to be further developed in detailed workshop planning and will be influenced by available resources.

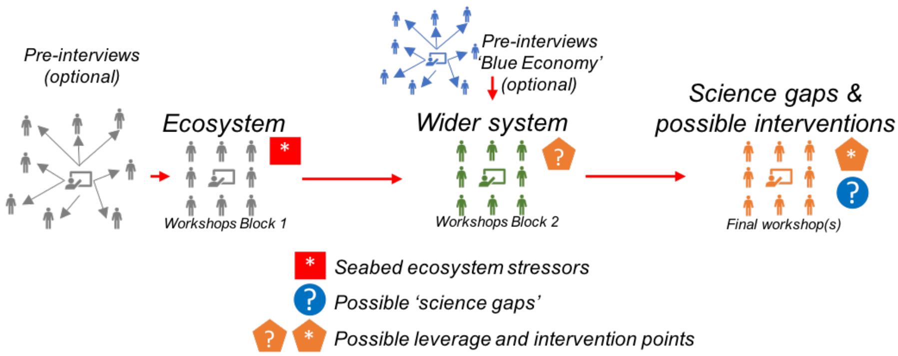
6.2.1 Process for Options 1 & 2

The conceptual process is shown below in Figure 8.

1. Identify process participants.
2. Key participants will be interviewed before the workshops. Given that the work is not starting from a 'blank slate' for either Option 1 or 2, this will enable the facilitator to develop a concept map which will be used in the first workshop.
3. A series of 2 workshops (Workshop block 1) will develop a map of the seabed ecosystem and the main stressors affecting its health.
4. A series of optional interviews may be undertaken with participants in the 'Blue Economy' work, which will help to inform the wider system map that is developed in Workshop block 2
5. A series of 2-4 workshops (block 2) will develop a wider system map of the factors and influences that are affecting the stressors of the seabed ecosystem.
6. All of the work above will build an understanding of the potential science gaps and leverage areas where intervention may be undertaken in the system. A further 1-3 workshops (block 3) will collate all of these insights and seek group alignment on

science needs for EBM (for the Managed Seas work), factors requiring valuation (for the Valuation project) as well as possible leverage points that might be useful for EBM — to demonstrate the need to align policy across agencies and generate a group that is ready, willing and able to trial EBM.

Figure 8. Conceptual diagram of the process for both options 1 & 2.



** Note: While the conceptual process is the same for both options 1 & 2, the difference is in the profile and number of participants and the amount of time taken at each step.*

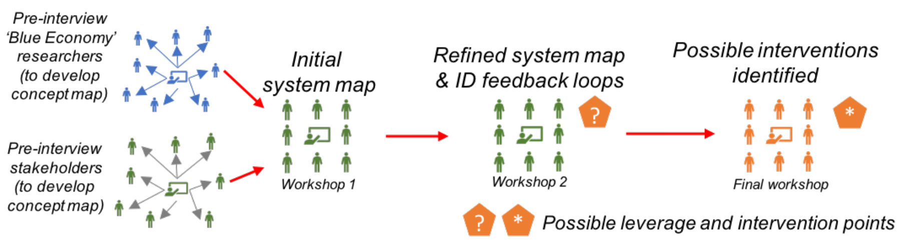
6.2.2 Process for Option 3

The conceptual process for a third option is shown below in Figure 9. It is assumed that resources are constrained to 2-3 workshops and that this be considered a 'pilot' for how system mapping may be used in EBM. The same problem relating to declining seabed health is assumed and as it is a pilot, it will be determined in the detailed planning stage whether the systems mapping is: a) undertaken at a smaller geographical scale; or b) undertaken across the entire TBGB area but at a higher level of aggregation.

The following components of the process will be undertaken in this 'pilot'. It will also focus on the whole system from the beginning, removing the initial focus on a seabed 'sub-system' outlined in the first two options.

1. Identify process participants.
2. Pre-workshop interviews are undertaken with participants and Blue economy researchers to contribute to a concept map (developed by the facilitator) ,which will be used in the first workshop. This also allows the concept of system mapping to be introduced to participants early on.
3. Beginning with the concept map, workshop 1 will develop a map of the factors contributing to the declining seabed health.
4. Workshop 2 will refine the system map from the initial workshop, as well as undertake some analysis of the system with the group. This will focus on the identification of feedback loops as a means to understanding behaviour.
5. In the final workshop potential areas of leverage in the system and intervention points are explored, as a means of testing the applicability of the system mapping approach for use in EBM as well as identifying science gaps and valuation needs.

Figure 9. Conceptual diagram of the process for Option 3



6.3 Resources

Estimating the resources required to run a system mapping process is very difficult at the conceptual stage. So many variables will influence the resources required, including (but not limited to): the actual size of the geographic area that will be focused on; the number of people required to be involved, and; the existing level of cooperation and goodwill between participants.

Note that for workshop scenarios, a maximum of 12 people has been assumed for each workshop. Experience (and the literature (Vennix, 1996; van den Belt, 2004) indicate that this is a realistic maximum for work within a single group. This does not mean that workshops are constrained to this maximum number and it is possible to involve a larger number of people in the workshop process. However, this will have an impact on the number of sessions and the number of facilitators with an in-depth knowledge of systems mapping required. If more than 12 people were to be involved, then a larger number of workshops will be required.

It is noted that there are a number of iwi in the TBGB area who need to be to be involved in the systems mapping process. The iwi representatives alone (8-12 people) could nearly fill one workshop to capacity (12 people). Therefore, the table estimating the time and cost involved (Table 2 and Table 4) assumes time and cost for a set of 12 participants, as well as 24 participants. This is not a suggestion that all iwi should be in their own parallel workshop stream, it simply allows for a number of people to be involved. Exact workshop participation is yet to be determined.

Where participants numbers are assumed at double (24 instead of 12) for a workshop, the resources required are assumed as 1.5 times the amount for that assumed for 12. This acknowledges that some tasks will be common across all workshops at a single step, but still allows for the significant effort involved in running a single day workshop.

Interviewing participants before the first workshop is intended to socialise the process with them earlier, enabling them to provide their perspective on the system to the facilitator. This will allow a concept map to be developed, and issues such as an appropriate level of aggregation and the system boundary will have been partially worked through with participants. This will ensure that workshop time is focused on exploring and aligning shared mental models of the system, thus increasing participants shared understanding of the system. Although pre-workshop interviews are listed optional, they are recommended to ensure a more robust result.

Although all workshops listed are assumed as full one-day workshops, it should be noted that preparation for and follow up from a single one-day workshop can mean the total work required is around four days. This allows for 1.5 days of preparation before a workshop, as well as 1.5 days for the drawing and analysis of the system map after a workshop, to summarise it or prepare for the next one.

The estimates only include time for Justin Connolly form Deliberate. No allowance has been made of any other staff. Similarly, no allowances have been made for venue costs, or travel related costs. All of these costs are difficult to estimate so will all be in addition to the staff time costs listed here. It is assumed that other Sustainable Seas staff will lead the coordination, contacting and communication with participants and the venue booking.

6.3.1 Resources for Options 1 & 2

A summary estimate of resources likely to be required in conceptual options 1 & 2 is shown in Table 2.

Table 2. Comparison of conceptual options – components of work likely to be required

Component	Option 1: High level of coordination with 'Managed Seas' work			Option 2: Low level of coordination with 'Managed Seas' work		
	Description	Indicative time/cost (12 ppl)	Indicative time/cost (24 ppl)	Description	Indicative time/cost (12 ppl)	Indicative time/cost (24 ppl)
Identify participants	To be done by existing project staff. Advice and input only.	0.5 days	0.5 days	To be done by existing project staff. Advice and input only.	0.5 days	0.5 days
Pre-interviews of participants (optional)	5 hours **per participant** assumed. **2 hours** of interview time plus coordination, travel and write up time.	7.5 days	15 days	5 hours **per participant** assumed. **2 hours** of interview time plus coordination, travel and write up time.	7.5 days	15 days
	1 day to draft interview findings into a 'concept map' for use in workshops.	1 day	1 day	**1 day** to draft interview findings into a 'concept map' for use in workshops.	1 day	1 day

Component	Option 1: High level of coordination with 'Managed Seas' work			Option 2: Low level of coordination with 'Managed Seas' work		
	Description	Indicative time/cost		Description	Indicative time/cost	
		(12 ppl)	(24 ppl)		(12 ppl)	(24 ppl)
Workshop Block 1	**2 one-day workshops** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people.	8 days	12 days	**2 one-day workshops** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people.	8 days	12 days
Interviews with 'Blue Economy' researchers (optional)	Approximately **1-2 days** of working with key research staff from the 'Blue Economy' work. This will explore the findings from this research and identify parts that may be useful to the system mapping.	1-2 days	1-2 days	Approximately **1-2 days** of working with key research staff from the 'Blue Economy' work. This will explore the findings from this research and identify parts that may be useful to the system mapping.	1-2 days	1-2 days
Workshop Block 2	**2-4 one-day workshops** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people. *This is anticipated to be more than Option 2 as it is anticipated that the interaction with the 'Managed Seas' work may require slightly more effort.*	8-16 days	12-24 days	**2 one-day workshops** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people.	8 days	12 days

Component	Option 1: High level of coordination with 'Managed Seas' work			Option 2: Low level of coordination with 'Managed Seas' work		
	Description	Indicative time/cost		Description	Indicative time/cost	
		(12 ppl)	(24 ppl)		(12 ppl)	(24 ppl)
Final workshop(s)	**1-3 one-day workshop(s)** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people. *This is anticipated to be more than Option 2 as it is anticipated that the interaction with the 'Managed Seas' work may require slightly more effort.*	4-12 days	6-18 days	**1-2 one-day workshop(s)** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people.	4-8 days	6-12 days
Indicative cost	**Workshop only option** **Total number of days**	**20.5 to 36.5**	**30.5 to 54.5**	**Workshop only option** **Total number of days**	**20.5 to 24.5**	**30.5 to 36.5**
	Workshop and pre-interview option (interview participants and Blue Economy) **Total number of days**	**30 to 47**	**47.5 to 72.5**	**Workshop and pre-interview option (interview participants and Blue Economy)** **Total number of days**	**30 to 35**	**47.5 to 54.5**

6.3.2 Resources for Option 3

This option is derived in response to an indication from project management that it is likely that only 2-3 workshops will be available. Additional resource to supplement this would be the resource required for 1-2 researchers to undertake interviews of participants, as well the time of the other researchers working on the 'Blue Economy' work. As noted earlier, each workshop is likely to require 4 days work relating to organisation, coordinating participants, preparation of materials and follow up from each workshop (summarising and/or preparation for the next workshop).

Table 3. Comparison of conceptual options – components of work likely to be required

Component	Option 3: Independent of 'Managed Seas' work		
	Description	Indicative time/cost	
		(12 ppl)	(24 ppl)
Identify participants	To be done by existing project staff. Advice and input only.	0.5 days	0.5 days
Pre-interviews of particpants (optional)	5 hours **per participant** assumed**. 2 hours** of interview time plus coordination, travel and write up time. **1 day** to draft interview findings into a 'concept map' for use in workshops.	7.5 days 1 day	15 days 1 day
Interviews with 'Blue Economy' researchers (optional)	Approximately **1-2 days** of working with key research staff from the 'Blue Economy' work. This will explore the findings from this research and identify parts that may be useful to the system mapping.	1-2 days	1-2 days
Workshop 1	**1 one-day workshop** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people.	4 days	6 days
Workshop 2	**1 one-day workshop** for a maximum of 12 people. For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people. *This is anticipated to be more than Option 2 as it is anticipated that the interaction with the 'Managed Seas' work may require slightly more effort.*	4 days	6 days

<table>
<tr><th rowspan="3">Component</th><th colspan="3">Option 3:
Independent of 'Managed Seas' work</th></tr>
<tr><th rowspan="2">Description</th><th colspan="2">Indicative time/cost</th></tr>
<tr><th>(12 ppl)</th><th>(24 ppl)</th></tr>
<tr><td>Final workshop(s)</td><td>1 one-day workshop for a maximum of 12 people.
For 24 people, twice the number of workshops assumed, at 1.5 times the time required for 12 people.
This is anticipated to be more than Option 2 as it is anticipated that the interaction with the 'Managed Seas' work may require slightly more effort.</td><td>4 days</td><td>6 days</td></tr>
<tr><td rowspan="2">Indicative cost</td><td>Workshop only option
Total number of days</td><td>12.5</td><td>18.5</td></tr>
<tr><td>Workshop and pre-interview option (interview participants and Blue Economy)
Total number of days</td><td>22
to
23</td><td>35.5
to
36.5</td></tr>
</table>

7 Assessing the options and recommendation

The previous sections outlined the three conceptual options, what they would involve, and an estimate of the resources required to deliver them. This section will assess the options and provide a recommendation.

7.1 Assessing the options

The three options are assessed according to a range of criteria.

Firstly, they are assessed against the **project purpose** as articulated in the CP2.1 planning meeting and noted in the Introduction. For clarity these are noted again here:

- Trialling participatory practices and science tools.
- Building shared understandings of the 'system' (ecosystem)
- Building new understanding of EBM and what this means for the possibilities of implementing EBM.
- Fostering a community that is ready, willing and able to apply/trial EBM.

In addition to the four points of the purpose, above, the options are also summarily assessed for their fit with: **other Managed Seas work**; the **timeline** remaining for CP2.1 (to June 2019); and the likelihood that they are **financially suitable**. The author is unaware of budgetary constraints, apart from the indication that was made that there may only be resource for 2-3 workshops. Therefore, this assessment is more relative to each other than to a known budget.

Finally, some **risks** associated with each option are noted.

The assessment is provided in Table 4 (following).

Table 4. Tabulated assessment of the three options

Criteria	Option 1: High level of coordination with 'Managed Seas' work	Option 2: High level of coordination with 'Managed Seas' work	Option 3: Independent of 'Managed Seas' work
Trialling participatory practices and science tools *From project purpose*	• Overview of how current 'Managed Seas' research and tools represent the various elements of the system. Potential gaps identified. • Option for participatory process workstream to be heavily involved in this option.	• System map available for 'Managed Seas' research to explore if there are possible gaps in the research. • Option for participatory process workstream to be fairly heavily involved in this option.	• System map expected to only cover: a) a limited geographical area; or b) a much more aggregated level of detail. • Option for participatory process workstream to be moderately involved in this option.
Building shared understandings of the 'system' (ecosystem) *From project purpose*	• High-level system map of factors influencing seabed health in TBGB. • Very high levels of shared understanding between workshop participants about factors causing issues and areas to intervene. This would have been developed with input from Managed Seas researchers, so maximises the likelihood that these insights will also be included in other Managed Seas modelling/tools. •	• High-level system map of factors influencing seabed health in TBGB. • High level of shared understanding between workshop participants about factors causing issues and areas to intervene. This would have only been developed with partial input from Managed Seas researchers, mostly around the seabed 'sub-system'. Therefore, the likelihood insights from the wider system are included in other Managed Seas modelling/tools is reduced. •	• Very high-level (maybe only partial) system map of factors influencing seabed health in TBGB. May only cover a partial geographical area, not the entire TBGB. However, given the application of this as a 'pilot', this is a realistic outcome and not seem as a limitation. • Moderate level of shared understanding between workshop participants about factors causing issues and areas to intervene. This would have only been developed with partial input from Managed Seas researchers, mostly around the seabed 'sub-system'. Therefore the likelihood insights from the wider system are included in other

Criteria	Option 1: High level of coordination with 'Managed Seas' work	Option 2: High level of coordination with 'Managed Seas' work	Option 3: Independent of 'Managed Seas' work
			Managed Seas modelling/tools is reduced.
Building new understanding of EBM and what this means for the possibilities of implementing EBM *From project purpose*	• A very highly increased level of understanding of the interconnectedness of the system and how this knowledge may support EBM. • An excellent idea of how system mapping may be used in an EBM context.	• A highly increased level of understanding of the interconnectedness of the system and how this knowledge may support EBM. • A very good idea of how system mapping may be used in an EBM context.	• An increased level of understanding of the interconnectedness of the system and how this knowledge may support EBM. • Clear insight into how research into the use of systems mapping can be applied in tranche 2.
Fostering a community that is ready, willing and able to apply/trial EBM *From project purpose*	• Very high levels of trust established with participants, but not all subject areas covered. • Participants are expected to experience very high levels of engagement with the process. • There is the potential that such an involved process will not be seen as research, but actually doing EBM. • Participants have ample time to develop trust with each other.	• High levels of trust established with participants, but not all subject areas covered. • Participants are expected to experience high levels of engagement with the process. • There is the potential that such an involved process will not be seen as research, but actually doing EBM. • Participants have ample time to develop trust with each other.	• A moderate level of enthusiasm and buy-in for further system mapping work may be generated for future research into EBM approaches. • Participants are expected to experience the high levels of engagement with the process and a strong desire for more. This is based on high levels of marginal satisfaction experienced in initial workshops (Connolly, 2017). • Moderate levels of trust established with participants, but not all subject areas covered.

Criteria	Option 1: High level of coordination with 'Managed Seas' work	Option 2: High level of coordination with 'Managed Seas' work	Option 3: Independent of 'Managed Seas' work
Ability for the system map (the output) to integrate with; inform; or be informed by, other Managed Seas work	• Very high level of integration of system map with other Managed Seas research.	• Moderate level of integration of system map with other Managed Seas research. • Lack of involvement of all participants with other parts of the system limits the ability of the process to increase trust.	• Minimal level of integration of system map with other Managed Seas research. • Clear idea of how this approach may help to inform other work in future tranches of the Science Challenge.
Ability to deliver before Jun 2019	• Given the other commitments of project staff; the commitments of scientists and stakeholders; and the fact that Christmas/summer holidays are in the middle of the timeframe, the ability to achieve this in the timeframe is considered very low. Especially if 24 people need to be involved.	• Given the other commitments of project staff; the commitments of scientists and stakeholders; and the fact that Christmas/summer holidays are in the middle of the timeframe, the ability to achieve this in the timeframe is considered moderately low. Especially if 24 people need to be involved.	• Given the limited number of workshops, this option is very achievable within the timeframe. • It is expected that it could be delivered either side of the summer holidays (preferably before) so as to limit the impact of that on the process.
Cost (relative to other options)	• The combinations of this option are the most expensive as a it includes participants and scientists as much as possible. • This comes with a heavy resource burden though, and is likely to impact on the timeline, given the ongoing need for participants availability.	• The combinations of this option are in the middle of the price range. However, there are associated risks with this (see below). • This also still comes with a heavy resource burden and is still likely to heavily impact on the timeline, given the ongoing need for participants availability.	• This option has the lowest cost. • Risks associated with this are minimised due to this being run as a 'pilot' system mapping exercise.

Criteria	Option 1: High level of coordination with 'Managed Seas' work	Option 2: High level of coordination with 'Managed Seas' work	Option 3: Independent of 'Managed Seas' work
Risks	• May be difficult to achieve in timeframe due to the need for a high level of research involvement from existing research programmes. • May be difficult to secure consistent participant involvement for the number of workshops planned; this would impact on quality of the output. • Iwi in particular may have difficulty participating at the level anticipated and might not participate at all. • A comprehensive system mapping approach at this stage of research may be viewed as mal-coordinated and reflect badly on the Science Challenge. • While the ability of this option to better inform other Managed Seas work is seen as a significant benefit, this may also result in a consequential impact on resourcing on those other projects, due to the need to incorporate insights from this work.	• Potential disconnection between system mapping outputs and Managed Seas outputs. • Possibly less-robust system map if there is less researcher input. • Participants in Workshop Block 2 (mapping wider system) may not accept or trust map of ecological sub-system done in Workshop Block 1. • Level of participation is lower but still significant. • May be difficult to secure consistent participant involvement for the number of workshops planned; this would impact on quality of the output. • Iwi in particular may have difficulty participating at the level anticipated and might not participate at all. • A comprehensive system mapping approach at this stage of research may be viewed as mal-coordinated and reflect badly on the Science Challenge.	• Output system map not as comprehensive and likely to only cover a certain area, be highly aggregated. • Disconnection between systems mapping outputs and Managed Seas outputs is likely. As process is a 'pilot' the impact of this will be low. • While reduced, the risk of Iwi having difficulty participating remains. •

7.2 Recommendation

The three options provide a range of ways to approach systems mapping on the Sustainable Seas National Science Challenge. Option 1 provides a highly comprehensive approach that seeks a high level of involvement of both technical and non-technical stakeholders from the beginning. This would seek to be highly coordinated with the other Managed Seas work being undertaken. Option 2 provides a slightly less inclusive but still comprehensive approach to system mapping. This would be less coordinated with the other Manages Seas work, but still available for that work to draw from. Option 3 offers a parsimonious option to pilot participatory systems mapping as part of an already advanced programme of scientific work. This may provide an opportunity to explore this approach more fully in future tranches of the Science Challenge.

While pre-workshop interviews have been listed as optional in this report, they are recommended as a way of socialising systems mapping with participants and building trust in the process. All discussion below assume that pre-workshop interviews are included.

Time and cost are both very real constraints on this project, with the CP2.1 project needing to be completed by June 2019. Of all three options, Option 1 is considered the most desirable as it is the most comprehensive. However, it is also the most expensive and least likely to be delivered within the timeframe as it requires a significant burden of involvement from participants.

Option 2 is considered the least desirable. This is because it also runs the risk of being difficult to deliver with the timeframe, being expensive to deliver, and likely sets an expectation that insights from this WILL be incorporated into other Managed Seas work, when the coordination with that work is much reduced. In short, it still sets high expectations with a reduced capacity to deliver on those.

If it is taken that Option 1 & 2 will be difficult to achieve within the timeframe and that a partial or compromised outcome is not desired, then Option 3 remains the most viable option. While this is a much-reduced process and may only deliver a map of a particular area or a partial map, it still has many benefits. Firstly, it is pitched as a ‘pilot’ and so this can manage the expectations around what will happen with the outcomes. It is very cost effective, and further, it socialises the concept of systems mapping not just with stakeholders and participants, but with the wider community of scientists working on the Challenge. This provides an opportunity to consider how it may be better leveraged and used to the advantage of Managed Seas (or other) work in future tranches of the Science Challenge. Further, given the ‘pilot’ nature of this approach, it is recommended that participants be capped at 12.

Therefore, it is recommended the ‘pilot’ option outlined in Option 3, with a maximum of 12 participants, is adopted for the CP2.1. project.

8 Additional considerations for publication of results

One of the drivers of National Science Challenges is the publication of papers in peer reviewed academic journals. For successful publication of system mapping results in higher-ranking systems journals, it would be useful (if not a necessity) to demonstrate the impact that the system mapping project had on the mental models of participants or the decision-making process of which they were a part. This should be borne in mind when planning for these workshops.

While it is unlikely that any impact on decision-making will be demonstrated in the timeframe of this work – this is only research at this stage and while this work may eventually inform decision-making, it will not be for some time. However, it is expected that the methodological foundations to measure the impact of this approach on decision-making can be laid, with appropriate pre-test methods being applied. If further system mapping occurs later on or is incorporated into EBM in the future, then appropriate post-test methods may be applied at that stage and compared to the pre-test results gathered here.

Similarly, appropriate pre-test and post-test methods may need to be applied to this research to be able to demonstrate any impact on shared understanding and participants mental models.

Methods for how this may be done have not been suggested in these conceptual options, nor have resource requirements been considered. Any resource requirements, however, are expected to be low in comparison to the amount required for the overall methodology.

9 Conclusion

This report explores the use of systems thinking using system mapping to support the CP2.1 project on the Sustainable Seas National Science Challenge. Three options are described, discussed and assessed according to a range of criteria. Option 1 is considered the most desirable and Option 2 the least. Yet both of these are likely to be difficult to achieve within the limited timeframe remaining on the project anyway, Therefore, Option 3 is recommended as the best approach. While this is much easier to deliver within the timeframe, it also provides a pathway for familiarising stakeholders and other researchers with the systems approach, while also providing a research opportunity to best leverage this approach into future tranches of the Science Challenge.

Further detailed design and planning, including identifying stakeholders and more clearly estimating resource, will be required to fully scope any workshops. This is beyond the scope of this report.

10 References

References are normal font with a hanging indent of 1.27cm, as below:

Connolly, J.D. (2017). *Group model building to understand 'wicked' problems in New Zealand freshwater management* (Master's thesis, University of Waikato, Hamilton, New Zealand). Retrieved from https://researchcommons.waikato.ac.nz/handle/10289/11570

Forrester, J. W. (1961). *Industrial dynamics*. Cambridge, MA: The MIT Press.

Forrester, J. W. (1969). *Urban Dynamics*. Cambridge, MA: The MIT Press.

Hovmand, P. S., Andersen, D. F., Rouwette, E., Richardson, G. P., Rux, K., & Calhoun, A. (2012). Group model-building 'scripts' as a collaborative planning tool. *System Research and Behavioural Science, 29*, 179-193.

Rouwette, E. A. J. A., Vennix, J. A. M., & van Mullekom, T. (2002). Group model building effectiveness: a review of assessment studies. *System Dynamics Review, 18*(1), 5-45.

Senge, P.M. (2006). The fifth discipline – the art and practice of the learning organisation (2nd ed). London, United Kingdom: Random House.

Sterman, J. D. (2000). *Business dynamics: Systems thinking and modelling for a complex world*. New York, NY, USA: McGraw-Hill.

Scott, R. J., Cavana, R. Y., & Cameron, D. (2016). Recent evidence on the effectiveness of group model building. *European Journal of Operational Research, 249*, 908-918. doi: 10.1016/j.ejor.2015.06.078

van den Belt, M. (2004). *Mediated modelling: A system dynamics approach to environmental consensus building*. Washington, DC, USA: Island Press.

van den Belt, M., Shiele, H., & Forgie, V. (2013). Integrated freshwater solutions - A New Zealand application of mediated modelling. *Journal of the American Water Resources Association, 49*(3), 669-680. doi:10.1111/jawr.12064

Vennix, J. A. M. (1996). *Group model building: facilitating team learning using system dynamics*: Wiley.