National SCIENCE Challenges

SUSTAINABLE SEAS

Ko ngā moana whakauka

Developing decision-support tools for cumulative effects management

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Report for Sustainable Seas National Science Challenge project *Tools for incorporating ecological response to cumulative effects into management action (Project code 1.2)*

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For more information on this project, visit: https://www.sustainableseaschallenge.co.nz/our-research/spatially-explicit-cumulative-effects-tools/

About the Sustainable Seas National Science Challenge

Our vision is for Aotearoa New Zealand to have healthy marine ecosystems that provide value for all New Zealanders. We have 75 research projects that bring together around 250 scientists, social scientists, economists, and experts in mātauranga Māori and policy from across Aotearoa New Zealand. We are one of 11 National Science Challenges, funded by the Ministry of Business, Innovation & Employment.

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Cover image: A typical Aotearoa New Zealand coastal seascape (Photo credit: Carolyn Lundquist).

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We thank our co-development partners that helped us along our journey: Hannah Jones (Ministry for the Environment), Oliver Wade (Marlborough District Council), Anna Madarasz-Smith (Hawke's Bay Regional Council), Becky Shanahan (Hawke's Bay Regional Council), Megan Oliver (Greater Wellington Regional Council), and Shane Geange (Department of Conservation).

Contents

Executive summary

Managing cumulative effects in the coastal environment is challenging. Decision-support tools can be useful for informing resource management decision-making providing they meet certain prerequisites and requirements and are scoped appropriately.

Decision-support tools must focus on the specific needs of decision-makers. Being able to robustly describe the scientific concepts and processes relevant to the decisions to be supported, including ecological, hydrodynamic, and chemical processes, stressor-environment interactions, and, especially for cumulative effects, the interrelationships of stressors, is the most challenging prerequisite because of the inherent complexities in these concepts and processes. Due to scientific information gaps or uncertainties identified during this step it may not be possible to develop decision-support tools for some applications. However, supporting decision-making does not necessarily require mathematical tools. Communicating the scientific concepts and processes related to cumulative effects meaningfully to decision-makers, for example in form of best practice guidance, can provide very effective support.

Resource management decisions are important and enduring. Decisions are final and can have significant environmental, economic, societal, cultural, and legal consequences. For these reasons, decision-support tools must be scientifically robust. For the outputs of decision-support tools to effectively inform resource management decisions, they need to be ecologically meaningful and interpretable in the context of policies and plans. Another key requirement of decision-support tools is the ability to identify uncertainties because otherwise scientific experts could not rely on them if presenting evidence to council hearings or the Environment Court. Access to decision-support tools must be reasonable, in terms of timeliness and cost. The cost of using a decision-support tool should be proportionate to the value the tool adds to the decision-making process, recognising that any tool is only one of several scientific information sources.

A useful approach for illustrating the required scope of decision-support tools is the Driver-Pressure-State-Impact-Response (DPSIR) framework. Applying the DPSIR framework to resource management decision-making processes demonstrates that decision-support tools need to include pressure, state, and impact to ensure that outputs can be linked to pressures and that impact is made explicit so that it can be interpreted in the relevant policy framework.

Based on these prerequisites, requirements, and scoping considerations, we created a conceptual decision-support tool structure. We also identified five principles aimed at optimising the effectiveness of decision-support tools by enabling robust validation, encouraging uptake by decision-makers, and more strategically addressing scientific knowledge gaps. The ability to validate decision-support tools is improved if development starts with comparatively simple tools and if complexity is gradually added. The likelihood of implementation is maximised by working with decision-makers in the selection of tools to support resource management processes. Systematically compiling information gaps during the decision-support tool development could inform a more strategic approach towards addressing scientific knowledge gaps related to managing cumulative effects.

Introduction

Supporting the management of cumulative effects in the coastal environment

Managing cumulative effects is possibly the greatest challenge for the day-to-day management of the coastal environment by local authorities. The coastal environment is a multi-use space that experiences stressors both from land- and sea-based anthropogenic activities and natural stressors, many of which occur over multiple spatial and temporal scales. The coastal environment is highly dynamic and spatially variable, extensively connected with both the land and oceanic systems, and experiences high natural variability, ranging from localised short-term fluctuations to inter-decadal oscillations. Under these conditions, making decisions on people's interactions with and use of natural resources (required as part of resource consenting, policy and plan development and review, catchment management, or restoration), is extremely difficult.

Decision-support tools[1] can be useful for informing the management of cumulative effects in the coastal environment. However, developing effective decision-support tools is challenging and requires careful consideration of prerequisites, requirements, and scoping, which we discuss in this document.

Effective management of the cumulative effects of activities builds on an effective management of individual effects. Many challenges arising in the management of cumulative effects are also prevalent in the management of individual effects. For this reason, we expect that this report will be of interest to a wide range of scientific initiatives aimed at supporting resource management activities.

Prerequisites for decision-support tools

Effective decision-support tools rely on a range of prerequisites being met. When considering developing a decision-support tool, it is important to carefully examine the prerequisites illustrated in Figure 1 and check if they can be met with sufficient confidence.

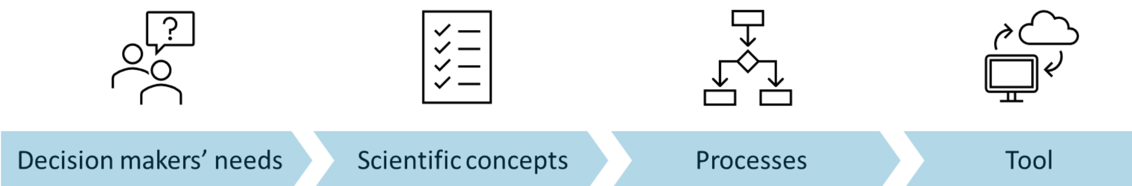

Figure 1: Prerequisites for the development of decision-support tools.

[1] For the purpose of this document, a tool is defined broadly as any mathematical tool that receives input(s), performs some computation(s) and produces output(s).

Prerequisite 1: Determine the needs of decision-makers

The most important aspect of developing decision-support tools is to identify and ensure robust understanding of the needs of decision-makers, including the types of decisions that are to be supported. Examples of decisions arising in the management of cumulative effects that may benefit from decision-support tools are listed in Table 1.

While most resource management decision-making involves assessing effects of activities, the value and effectiveness of decision-support, whether in form of a tool or otherwise, depend on the alignment with the exact nature and context of the specific decisions to be supported.

Table 1: Examples of decisions arising in the management of cumulative effects that may benefit from decision-support tools.

Resource management activity	Example of decisions that may benefit from decision-support tools
Resource consenting	• Are the (individual and cumulative) effects of the proposed activity consistent with the nature and magnitude of those allowed under policies and plans? • What are appropriate mitigation measures for a proposed activity? • What is the appropriate duration for a resource consent? • How can environmental effects of a proposed activity be monitored effectively?
Policy and plan development and review	• What is the appropriate activity status for an activity? • What are appropriate limits for the intensity of permitted activities in a water body? • What are appropriate locations for activities? • What are inappropriate locations for activities? • Do the cumulative effects of managed activities affecting a water body cause a net loss or gain of biodiversity? • How to effectively monitor policy/plan effectiveness?
Catchment management	• What improvements can be expected in the coastal environment from a catchment management activity? • Where in the catchment can management activities optimise environmental outcomes for the coastal environment? • What catchment management activity results in the greatest improvement of biodiversity values in the coastal environment?
Restoration	• How effective is a restoration activity in the coastal environment? • Where in the coastal environment can restoration activities optimise environmental outcomes? • What stressors impede the positive environmental outcomes of restoration activities in the coastal environment?

An important aspect to bear in mind is that decision-support tools are typically not used by decision-makers, but rather by scientists providing expert advice to decision-makers. As such, the primary purpose of decision-support tools is to provide scientific outputs of direct relevance to the decision-making process that scientific experts can use, alongside other information sources, to inform their advice to decision-makers.

Prerequisite 2: Describe the relevant scientific concepts and processes

The second prerequisite for developing decision-support tools is the ability to describe the scientific concepts, and processes relevant to the decisions to be supported. These aspects may include ecological, hydrodynamic, and chemical processes, stressor-environment interactions, and, especially for cumulative effects, the interrelationships of stressors. Scientifically, this step is the most challenging step of the tool development process because of the inherent complexities in these concepts and processes.[2] As a consequence of scientific information gaps or uncertainties identified during this step, it might be necessary or appropriate to decide against developing a decision-support tool (see section *Requirements* below).

This step provides an opportunity to systematically collate scientific information and knowledge gaps related to cumulative effects management, which could contribute to a national cumulative effects-focussed research strategy and/or support the objectives of existing strategies, such as the Regional Council Research, Science and Technology Strategy 2020[3] and the Coastal Special Interest Group Research Strategy[4] by encouraging science investment into these policy-driven science needs.

Whether or not this step leads to the development of a tool, describing the scientific concepts and processes relevant to specific resource management decisions is a valuable process. Supporting decision-makers does not need to involve mathematical tools. Communicating these concepts and processes meaningfully to decision-makers, for example in form of best practice guidance, can provide very effective support. Such guidance could include a description of knowledge gaps, which would be helpful for decision-makers and may further incentivise science investment.

Requirements

Tools intended to be used for supporting resource management decision-making must meet a range of requirements, some of which are distinctly different from tools developed for other purposes (Figure 2).

[2] Rojas-Nazar, U., J. Hewitt, C. Pilditch, C. Cornelisen. 2023. Managing cumulative effects in the marine environment – research roundup. Summary report for the Sustainable Seas National Science Challenge. Crain, C. M., K. Kroeker, and B. S. Halpern. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters 11:1304-1315. Foley, M. M., R. G. Martone, M. D. Fox, C. V. Kappel, L. A. Mease, A. L. Erickson, B. S. Halpern, K. A. Selkoe, P. Taylor, and C. Scarborough. 2015. Using ecological thresholds to inform resource management: current options and future possibilities. Frontiers in Marine Science 2.

[3] Regional Council Science Advisory Group. 2020. Research for Resource Management Regional Council Research, Science & Technology Strategy. Access at https://www.envirolink.govt.nz/assets/Research-for-Resource-Management-2020.pdf

[4] Berkett, N., O. Wade, C. Cornelisen, M. Newton, K. Bell. 2015. Guiding coastal and marine resource management: The Coastal Special Interest Group Research Strategy. Prepared for C-SIG. Access at https://envirolink.govt.nz/assets/Envirolink/1535-HBRC207-Guiding-coastal-and-marine-resource-management.pdf

Decision-support tools must be scientifically robust

Resource management decisions are important and enduring. Decisions can have significant environmental, economic, societal, cultural, and legal consequences. Furthermore, decisions, such as granting resource consents or implementing new policies, typically remain in effect for several decades.

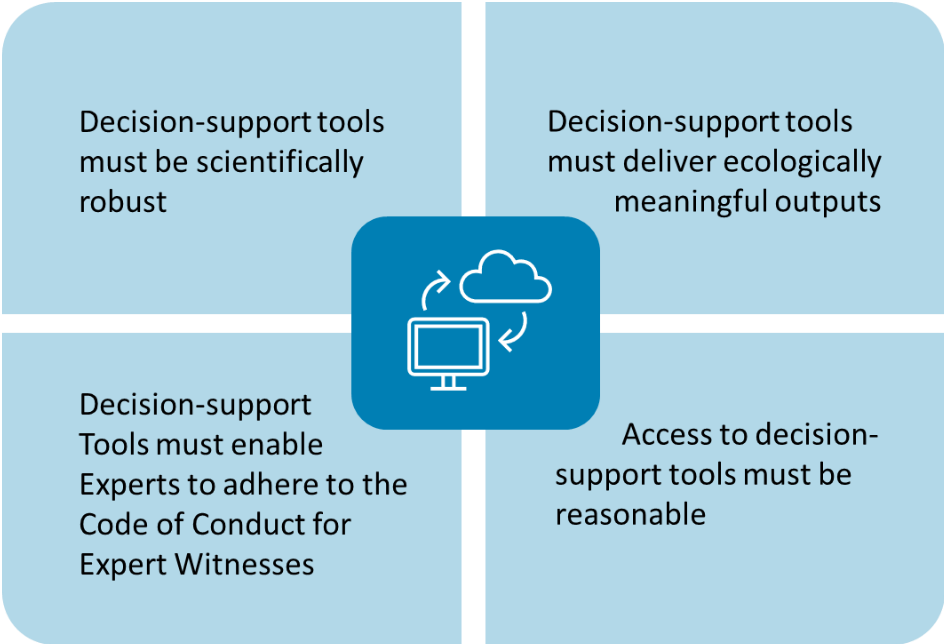

Figure 2: Requirements of decision-support tools.

For these reasons, any information generated by decision-support tools for informing these decisions must be scientifically robust. This requirement applies to all tool components, processes, and data used in the development, validation, and application of tools. An important aspect of ensuring scientific robustness is the identification of uncertainties, which is discussed in more detail below in relation to the Code of Conduct for Expert Witnesses.

Decision-support tools must deliver ecologically meaningful outputs

For the outputs of decision-support tools to effectively inform resource management decisions, they need to be interpretable in the context of policies and plans. Outputs should provide appropriate ecological context so that scientific experts using them to inform their advice to decision-makers can align them to the relevant policy framework.

For example, descriptors of benthic habitat, species, or community change should indicate whether effects are adverse or positive, which is not necessarily apparent if tools focus on describing environmental change in the absence of meaningful ecological thresholds. Furthermore, to achieve ecological meaningfulness, it should be possible to align decision-support tool outputs related to benthic habitats, species, or communities with concepts commonly used in coastal policy, such as ecosystem health, function, and services, habitats and species with particular conservation or cultural value, and the descriptors of the New Zealand Coastal Policy Statement 2010.

However, decision-support tools should not attempt to use planning terminology of the Resource Management Act 1991 (RMA), such as ‘more than minor’, as this classification is not a scientific classification and therefore outside the scope of scientific decision-support tools.

Decision-support tools must enable experts to adhere to the Code of Conduct for Expert Witnesses

Experts preparing evidence for council hearings or the Environment Court must adhere to the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2023. This means they must:[5]

- Identify the nature and extent of uncertainties in any scientific information and analyses relied on and the potential implications of any uncertainty.
- If relying on a mathematical model, include appropriate or generally accepted sensitivity and uncertainty analyses for that model.

For experts to rely on decision-support tools in their evidence, tools therefore need explicit information about uncertainties and sensitivities of the tool, including data used to develop and validate the tool. Many resource management processes warranting the use of decision-support tools involve a council hearing or Environment Court proceedings. Consequently, being able to identify uncertainties and sensitivities associated with any outputs is a core requirement of decision-support tools.

Access to decision-support tools must be reasonable

In addition to the prerequisites and requirements described above, a key factor influencing whether an available tool can be used to support a decision-making process is the reasonableness of access, both in terms of timeliness and cost. Decision-support tools can take many different forms and complexities. While some tools may be accessible widely and without the need for technical expertise, applying others to specific resource management processes requires specialist knowledge and skills and potentially costly and prolonged contracts with science providers.

The timeframes of some resource management processes, including resource consenting, are very short compared to typical timeframes for using comparable tools and models in a research context. Therefore, for decision-support tools to be utilised by experts in these processes, access to tools must be uncomplicated and quick.

The cost of using a decision-support tool should be proportionate to the value the tool adds to the decision-making process, recognising that any tool is only one of several scientific information sources. However, proportionality is a difficult concept in the management of effects, particularly cumulative effects, because the severity of environmental effects is not necessarily proportionate to the operational scale of an activity, including its financial investment and/or anticipated financial gains. There would generally be an expectation that expensive (in terms of cost and expert time) decision-support tools are only required for large-scale projects. However, especially for the management of cumulative effects, the use of decision-support tools needs to be independent of the operational scale of activities.

[5] Section 9.3(a) ix and x. Access at https://environmentcourt.govt.nz/about/practice-note/.

Anticipated applications and required conditions of access should be discussed with decision-makers as part of determining their needs under the first prerequisite described in this document to avoid unforeseen obstacles to utilising tools once they have been developed.

Scoping

Determining the scope of a decision-support tool is critical for ensuring it can provide effective support. A useful approach for illustrating the required scope of decision-support tools is the **DPSIR** (Driver, Pressure, State, Impact, Response) framework. Examples of how the DPSIR framework can be applied to resource management processes are shown in Figure 3 (resource consenting) and Figure 4 (catchment management).

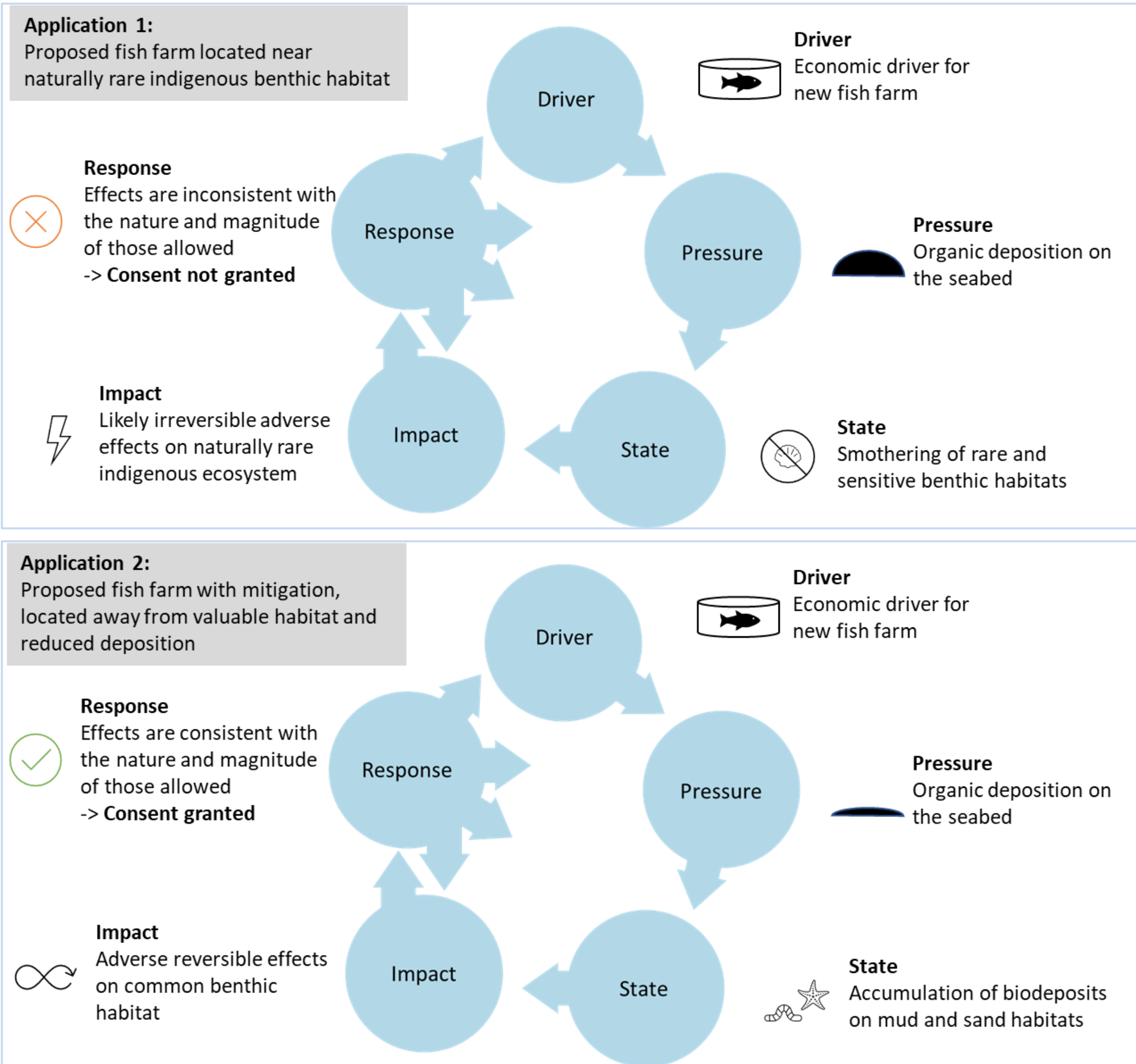

Figure 3: Example illustrating how the DPSIR framework can be applied to decision-making of a resource consent application for a fish farm, focusing on the single stressor 'organic deposition on the seabed'. Application 1 (top) represents an application for a fish farm located near naturally rare indigenous benthic habitat where effects are inconsistent with those allowed and the decision is made not to grant consent. Application 2 (bottom) represents the fish farm application following mitigation, including relocating the proposed farm and reducing deposition, which results in reduced environmental impact and therefore a decision to grant consent.

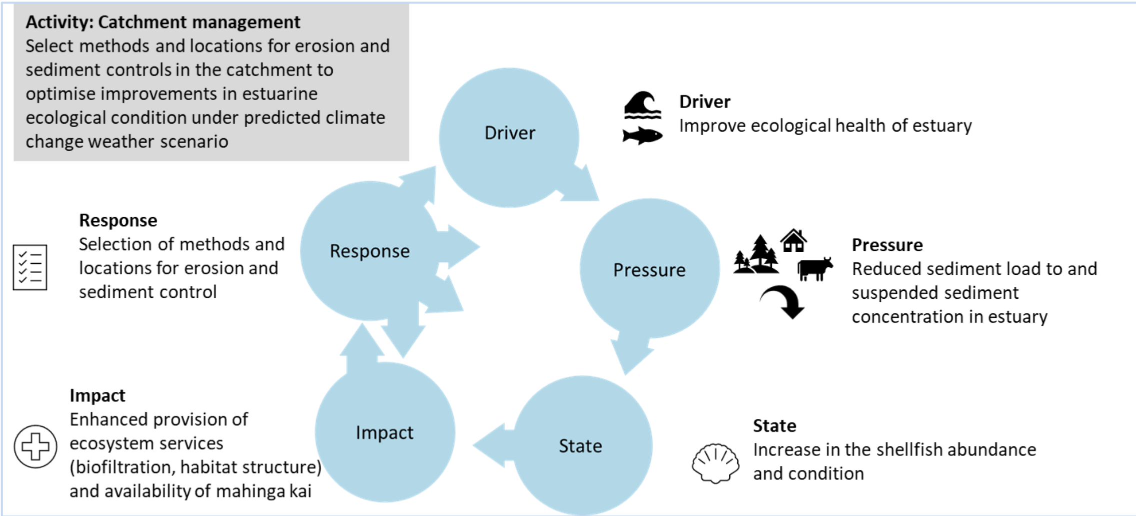

Figure 4: Example illustrating how the DPSIR framework can be applied to decision-making of methods and locations for catchment management activities aimed at achieving improvements in the ecological condition of an estuary receiving sediment input from the catchment under a predicted future climate change weather scenario. In this example, the pressure is positive as sediment load and suspended sediment concentration is reduced through erosion and sediment controls. By comparing changes in impact resulting from different methods and locations under a predicted weather scenario, the optimal selection can be chosen as that achieving best outcomes in terms of policy objectives.

As demonstrated by these examples, to provide effective support for resource management decision-making, decision-support tools need to:

1. Make impact explicit. By making impact explicit, tool outputs are ecologically meaningful and can be interpreted in the context of the RMA and relevant policies and plans.

2. Consider multiple pressures. Very few, if any, resource management decisions pertain to single pressures but instead involve multiple pressures and cumulative effects. In addition to the obvious scientific rationale, the RMA defines the term ‘effect’ as including cumulative effects, thus setting a clear expectation that effects assessment consider all relevant pressures.

3. Consider unmanageable pressures. Many pressures affecting the coastal environment are not manageable, including climate change and natural pressures. In order to support decisions on cumulative effects management, these unmanageable pressures need to be considered.

4. Consider natural variability and extreme events. Evaluating environmental effects of stressors in relation to natural variability and environmental change caused by extreme events is an important aspect of resource management.

Figure 5 illustrates the overall scope and the four key features of effective decision-support tools.

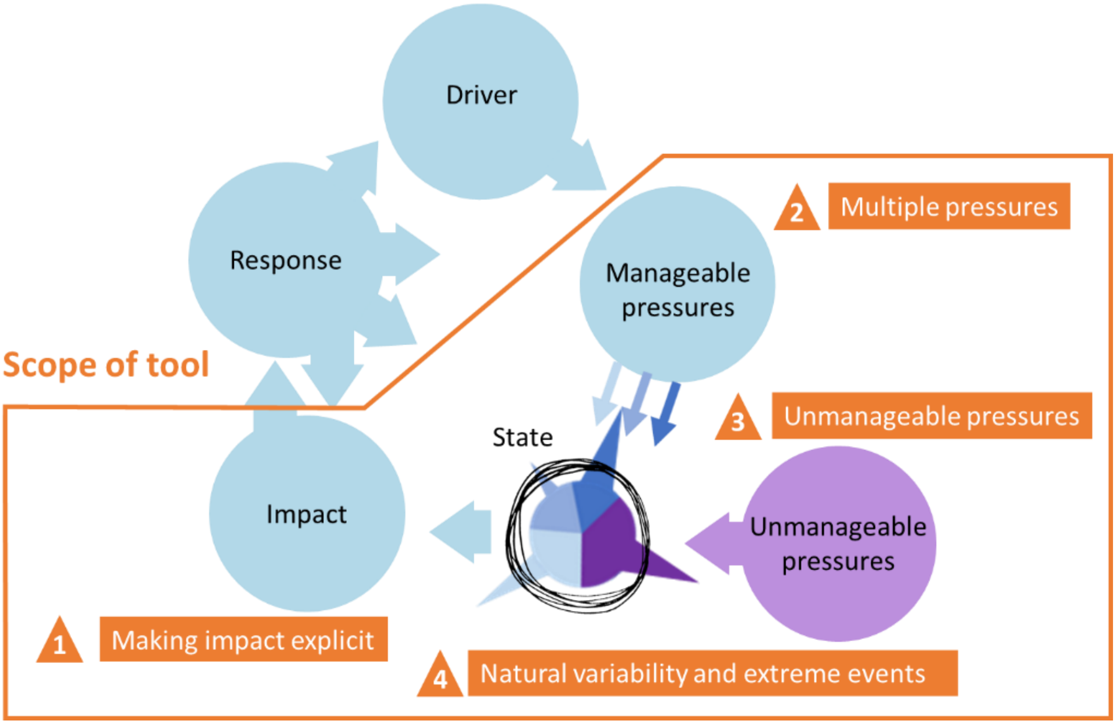

Figure 5: Scope and four key features of effective of decision-support tools. The line encircling 'State' and associated spikes represent natural variability and extreme events.

Conceptual decision-support tool structure

Based on the prerequisites, requirements, and scope considerations discussed in this document, we propose the conceptual decision-support tool structure shown in Figure 6.

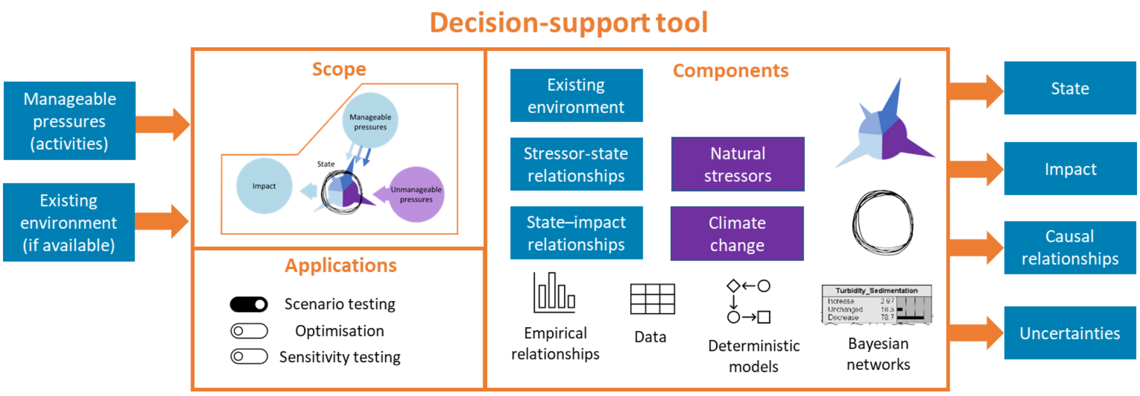

Figure 6: Conceptual decision-support tool structure.

The key features of the conceptual decision-support tool structure are:

- Inputs
- Scope
- Applications
- Components
- Outputs

Inputs to decision-support tools include the manageable pressures decisions focus on, for example, the activity for which resource consent is sought. Decision-support tools also need to provide options for providing environmental data, for example, data obtained from surveys conducted to inform the decision-making process, which can supplement the environmental data used to pre-populate the tool.

The **scope** of decision-support tools is discussed above and needs to include pressures, state, and impact.

Scenario testing is expected to be the main **application** of decision-support tools as this will enable testing and comparing the outcomes of options, which is an important process in resource management decision-making. Enabling an optimisation application, for example, the ability to identify a location for an activity that optimises specified environmental outcomes, would be a valuable feature. Sensitivity testing needs to be a core application of any decision-support tool aimed at informing resource management processes.

Decision-support tool **components** depend largely on the specific tool, including scientific and technical needs. We envisage that most decision-support tools would be spatial; however, that is not necessarily required for all applications.

Decision-support tools need to provide at least four types of **outputs**. Describing the environmental state and changes in state associated with scenarios provides relevant information about environmental parameters. In addition to the obvious general importance of describing changes in state, this is of particular importance for decision-making processes related to environmental monitoring (see example questions in Table 1).

As outlined in section *Scoping* above, a core requirement of decision-support tools is to provide ecologically meaningful outputs that make impact explicit and can be interpreted in the context of the RMA and relevant policies and plans. Resource management processes involving cumulative effects assessments and management require cause-and-effect relationships between stressors and effect to be established. Decision-support tools therefore need to provide the ability to make such linkages. Finally, identifying and quantifying uncertainties in all aspects of the decision-support tool is critical. This must include all types of uncertainties (e.g., those arising from the tool structure or uncertainties in stressor relationships) and enable decisions to be made by decision-makers on whether the level of uncertainty associated with tool outputs is acceptable for a specific application.

Principles for developing decision-support tools for cumulative effects management

Developing decision-support tools is difficult and at times impossible because of scientific knowledge gaps. However, we are confident that effective decision-support tools can be developed for many resource management applications if the development process follows the steps outlined in this document as well as the following additional principles:

1. Start developing new decision-support tools for applications with well-understood scientific concepts and processes.
2. Add one managed stressor at a time and gradually add complexity, including cumulative effects.
3. Maximise the likelihood of implementation by focussing on resource management processes that would benefit most from decision-support tools and being realistic about development timeframes.
4. Systematically identify knowledge gaps.
5. Seek opportunities to fill knowledge gaps.

The first two principles enable robust validation of early stages of decision-support tools because predicted outputs, including measures of uncertainty, can be compared against scientific knowledge. Gradually adding complexity enables the growing uncertainty associated with more complex and uncertain tool components, including stressor interactions, to be measured. This approach, in turn, supports proactive calls to be made about how much uncertainty to accept and tool development to be stopped or suspended until uncertainty has been reduced, for example through targeted scientific initiatives.

The third principle aims to maximises the likelihood of decision-support tools being implemented in actual resource management decision-making. In addition to identifying the resource management applications that would benefit most from decision-support tools, this principle also recognises the need to consider realistic development timeframes for decision-support tools, particularly the lag between the start of the tool development process and the point in time a tool is able to be used. This principle enforces the importance of working with decision-makers in the early stages of the tool development process, likely several years before the respective resource management process, for example, a policy or plan review or a resource consent application, commences.

The last two principles recognise that scientific information gaps will impede any decision-support tool and the importance of filling information gaps in order to increase the scientific robustness and decrease uncertainty of outputs of decision-making tools. These principles also reflect a positive spinoff as the scientific information gaps identified during the development of decision-support tools for cumulative effects could be systematically compiled and used to inform a more strategic approach towards addressing scientific information gaps.

Summary

Managing cumulative effects in the coastal environment is challenging. Decision-support tools can be useful for informing resource management decision-making, providing they meet certain prerequisites and requirements and are scoped appropriately. Importantly, decision-support tools must focus on the specific needs of decision-makers. Developing effective decision-support tools is complex and difficult. For many potential applications it will be impossible to develop decision-support tools that meet the needs of decision-makers, particularly the required level of scientific robustness and certainty. However, supporting decision-making does not necessarily require mathematical tools. Communicating the scientific concepts and processes related to cumulative effects meaningfully to decision-makers, for example in form of best practice guidance, can provide very effective support.

Decision-support tools should include pressure, state and impact to ensure that outputs can be linked to pressures, and that impact is made explicit so that it can be interpreted in the relevant policy framework. A key requirement of decision-support tools is the ability to identify uncertainties because otherwise scientific experts could not rely on them if presenting evidence to council hearings or the Environment Court. The ability to validate decision-support tools is improved if development starts with comparatively simple tools and if complexity is gradually added. The likelihood of implementation is maximised by working with decision-makers in the selection of tools to support resource management processes. Systematically compiling information gaps during the decision-support tool development could inform a more strategic approach towards addressing scientific knowledge gaps related to managing cumulative effects.

For further information

This conceptual framework builds on the experience of the authors and colleagues at Aotearoa New Zealand research institutes and government agencies in informing decision-making with respect to land- and ocean-based impacts.

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