He Tangata, He Taiao, He Ōhanga

a values-based biosecurity risk assessment framework for Aotearoa

NEW ZEALAND'S BIOLOGICAL HERITAGE

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Literature review of risk assessment and decision-making frameworks

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Gap analysis for risk assessment and decision making in the biosecurity system – literature review of risk assessment and decision making frameworks

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Summary

- The research programme "He Tangata, He Taiao, He Ōhanga[1]" (Strategic Outcome 3, New Zealand's Biological Heritage National Science Challenge) aims to incorporate information from a holistic set of values into a biosecurity risk assessment framework.

- This literature review is part of the first stage of that research programme, aiming to describe what is already available to support risk assessment and decision making in the biosecurity system.

- Searches were conducted for term sets such as "biosecurity decision framework", "biosecurity risk assessment framework" and "biosecurity risk analysis framework".

- 10 frameworks related to biosecurity decision making were found. These frameworks are described in terms of the components that they contained and how they addressed the different values (for example economic or social values).

- More risk assessment frameworks were found than could be reviewed in the available time. 23 frameworks were described in terms of their scope and how they addressed the different values.

- Many published frameworks were developed for specific purposes and cannot be adopted for other purposes without modification.

- While a number of frameworks mentioned a holistic set of values, very few addressed those values in detail. One framework contained a checklist for considering social and economic values. One framework contained descriptors for describing levels of impact for invasive species on human well-being.

- The design of frameworks needs to address more than just developing tools. The design also needs to consider those who will directly use the framework (for example, risk assessors), and those who will use the results of that framework (for example, decision makers who make decisions based on risk assessment).

[1] The people, the environment, the economy

Contents

"*The ability to make deliberative, long-term decisions is one of the few truly unique characteristics of Homo sapiens, right alongside our technological innovation and our gift for language. And we're getting better at it*." Steven Johnson, Farsighted

Introduction

What is good decision making?

It is surprisingly difficult to define a good decision. Intuitively, in our everyday lives, most of us conflate a good decision with a good outcome (Yates et al. 2003). In contrast, theorists of decision making point out that there is a clear distinction between a good decision and a good outcome (for example, see Baron and Hershey 1988). A good decision can still result in a bad outcome, and a bad decision can still turn out well. Given this conflict between theory and practice in defining a good decision, how can we know whether we make good decisions?

One common definition of a good decision is "the selection of the best alternative available at the time the decision was made." (Yates et al. 2003). This definition is simple and makes intuitive sense, but it also raises the important question of what the best alternative actually is. It also doesn't state *when* the "best alternative" is defined – was that at the time of the decision or in hindsight? The distinction is important, because cognitive biases such as outcome bias[2] and hindsight bias[3] mean that we may change our perception of the best alternative, depending on when we are asked.

Decision theory makes a clear distinction between the quality of a decision and the outcome. In the face of uncertainty, decision makers are assumed to prefer the option with the best *predicted* outcome. For example, in Expected Utility theory, one of the main models in normative decision theory[4], the best choice is the option with the greatest expected benefit, or utility (Steele and Stefánsson 2020). Options can be ordered or ranked in some rational way and best option can be calculated from an equation.

Explaining the issue from a slightly different angle, Edwards (1984) points out that decisions have uncertain results, and evaluating their quality depends on the stakes and odds (that is, the potential consequences, positive and negative, and the probability). In effect, he suggests that decision quality is a function of the risk of a decision.

However, when we are asked to judge the quality of decisions that we make, we don't base that judgement on what was, objectively, the best option at the time. We think much more broadly. The most important factors in judging whether we have made a good decision are how the decision turned out, the process we used to make the decision and how we felt while, or after, making it (Yates et al. 2003). Putting aside the difficulty of knowing the outcome for certain, the work of Yates

[2] Outcome bias leads us to rate a decision as better if it has a good outcome, even if the option chosen actually had a higher probability of a poor rather than a good outcome (Baron and Hershey 1988).

[3] Hindsight bias affects our ability to estimate the probability of a particular event once that event has happened. If we know that something actually happened, we assign it a higher probabilty than we would have assigned if we were asked the question before we knew what had happened, or if we know that something else happened (Fischhoff 1975).

[4] Normative decision theory considers how decision makers *should* make decisions, in theory, but a wealth of evidence indicates that this isn't what they actually do (for example, see Dillon 2003).

et al. (2003) highlights the importance of process and emotion in decision making. Making a decision is not just a cognitive process, but an emotional one (Elwyn and Miron-Shatz 2010).

Medicine provides a good illustration of this point. In the majority of cases, we expect to discuss treatment options with a doctor and make our own decision, even though we have no expertise in medicine and are not in a position to judge which treatment is objectively the best (Ratliff et al. 1999). If we are not happy with how the doctor communicates with us, we may not be happy with how things turn out, regardless of how well we recover.

More nuanced definitions of good decisions, and good decision making, take these human factors into account. For example, Milkman et al. (2009) propose that normative models provide a good basis for judging good[5] decisions, with some additional criteria. Based on normative models, a good decision should be:

- logical[6]
- insensitive to minor changes in context
- consistent with stated preferences

In addition, they propose the additional criteria that a good decision should:

- appear to the decision maker remain be a good decision on "cool, calm reflection"
- appear to be a good decision regardless of who the decision maker was

The last point above implies the concept of fairness in good decision making. While a good decision and a fair decision are not equivalent, the definitions are close enough to warrant comparison, especially when considering regulatory decisions that affect many people. Cox et al. (2017) defined a fair decision, in a regulatory context, as having the following traits:

- objectivity
- consistency/ reliability
- transparency
- accountability
- based on evidence

Implicit in many definitions of good decisions, and good decision making, is the concept that a good decision is not accidental. A one medical professional expressed the point: *the uninformed selection of an option that has a good outcome is luck, not a good decision* (Dow 1999). In the medical field, many authors conclude that a good decision making process or framework is central to the definition of what makes a good decision (for example, see Hamilton et al. 2017, Bujar et al. 2016, Elwyn and Miron-Shatz 2010, Edwards and Elwyn 2006, Becker et al. 2003, Ratliff et al. 1999).

Medical decision making tends to focus on individuals, but the importance of process is also emphasised for larger scale decisions affecting many people. For example, Syme at al. (1999) found process to be a main factor in perceptions of fairness for water allocation in Australia. NRC (2013) recognises the importance of a good process in making decisions on sustainability. Whether or not the process was fair is one of the criteria suggested for evaluating the quality of decisions on environmental management (Dietz 2003). Good processes for information gathering and analysis,

[5] Milkman et al. (2009) specifically defined "optimal" rather than good decisions.

[6] By logical, they state that a decision should be free from systematic mathematical errors, and transitive, that is, if A is preferred to B and B is preferred to C, then A should be preferred to C.

and effective decision making frameworks are recognised as necessary for good regulatory decision making in New Zealand (Manch 2017) and internationally (Donelan 2013).

One point not often discussed in relation to decision making is that, overall, humans are getting better at making decisions. In part, this improvement has come about because of greater knowledge. However a substantial part of the improvement has come as a result of improvements in the way we make decisions, that is, the decision-making process (Johnson 2018, Buchanan and O'Connell 2006).[7]

What are decision-making frameworks?

Decision frameworks, or decision-making frameworks, are one way to address the need for a good process in order to make good decisions. The defining feature of decision frameworks is that they result in some sort of action, such as to allowing certain goods to be imported, or conducting a surveillance or control programme. Even a decision to "do nothing" is an action in itself. A decision is distinct from a conclusion. A conclusion is a judgement formed on the basis of evaluating evidence, such as stating that the risk of a certain pest is moderate, or that one pest is a higher priority than another[8].

The definition of a decision framework varies, but this report uses three definitions that are relevant for decision frameworks to support biosecurity decision making (table 1). The first definition is that of the United States National Academy of Sciences (2013), which defines decision frameworks as "*conceptual structures and principles for integrating the economic, social, ecological, and legal/institutional dimensions of decisions*". The second definition is that of Lockie and Rockloff (2005), which defined decision frameworks as "*complexes of tools, conceptual models and institutional arrangements found, or proposed, within specific planning and decision-making situations*". The third definition is that of Rehfuess et al. (2019), which defines a decision framework as "*a structured approach for guideline panels or other decision-making bodies to consider the available evidence and to make informed judgements… this approach can comprise substantive criteria as well as procedural aspects*".

The definitions above have different parts to them, but each has a structural component to the framework. The structural component is referred to in different ways, for example as a structure, a model or a process. It provides the theoretical basis for decision frameworks, and it may also serve as the process itself, that is, the actual steps that are followed. In this report, the term "model" is used to describe the structural component, consistent with the definition of Lockie and Rockloff (2005) where the model shows how different parts of a decision framework fit together (Lockie and Rockloff 2005).

The three definitions differ largely in what else, apart from the model, they consider to be a component of a decision framework. The National Academy of Sciences (2013) definition includes principles. The Lockie and Rockloff (2005) definition includes institutional arrangements and tools.

[7] I may delete this paragraph

[8] The distinction between decision and conclusion helps to distinguish decision-making models and frameworks from decision support support systems and other tools. A decision support system gives a conclusion but the decision itself is a separate process, including, for example, consultation with affected parties. Some references use the terms "decision model" or "decision framework" to describe a decision support system. In the definitions of Lockie and Rockloff (2005), decision support systems are tools and this definition is used here.

The Rehfuess (2019) definition includes criteria. In this report, a decision framework includes at least one of these components, as well as the model.

Table 1 **Definitions of decision framework**

Definition	Components	Source
conceptual structures and principles for integrating the economic, social, ecological, and legal/institutional dimensions of decisions	**Model** (Conceptual structures) **Principles**	National Academy of Sciences (2013)
complexes of tools, conceptual models and institutional arrangements found, or proposed, within specific planning and decision-making situations	**Model** (Conceptual model) **Tools** **Institutional arrangements**	Lockie and Rockloff (2005)
a structured approach for guideline panels or other decision-making bodies to consider the available evidence and to make informed judgements… this approach can comprise substantive criteria as well as procedural aspects.	**Model** (Structured approach/ procedural aspects) **Criteria**	Rehfuess et al 2019

In this report, a decision framework consists of a conceptual model and at least one of the other components such as principles or criteria. Risk assessment (or risk analysis[9]) fits within decision frameworks as a specific tool (Lockie and Rockloff 2005), but there can also be frameworks for risk assessment; these are discussed in the section on risk assessment frameworks.

Decision models

Decision models, or decision-making models, all have common elements. At a minimum, models have at least three elements, seen in figure 1 below (Simon 1960 in Dillon 2003). The three elements are:

- intelligence, or becoming aware of the need for a particular decision. This element broadly equates to "problem definition", the term I use in this report
- design, investigating the problem and developing alternatives.
- choice, actually making the decision

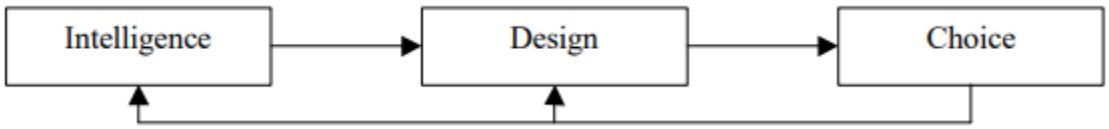

Figure 1. **Simon's model of the decision process, from Dillon (2003).**

Models for regulatory decision making all have these elements, although they are described in different ways. Two generic examples are used in this report. The first is an example from Donelan (2013) in an article on good regulatory decision making (figure 2).

[9] Define the two terms in terms of ISO 31000

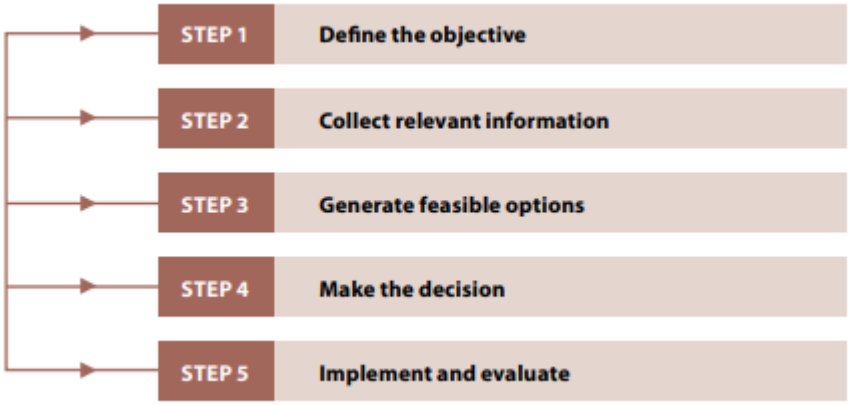

Figure 2. **Model for regulatory decision making (Donelan 2013).**

While simple, this model is a useful basic structure for decision making. It is used in this report for the purpose of comparing the different models and frameworks.

The second generic model for decision making is the "Dialogue Decision Process" from the Strategic Decisions Group (see Tani and Parnell 2013). This model has similar process steps to the generic ones in the first model from Donelan 2013. However at each stage there is an exchange between two groups, the decision making group (called the decision board) and an advisory group (called the project team). This model is useful for any decision which requires significant information gathering and analysis, as it is common to have this function separated from decision making.

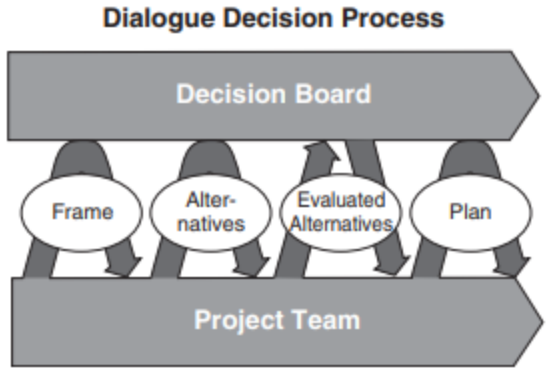

Figure 3. **Dialogue decision process (Strategic Decisions Group in Tani and Parnell 2013).**

The individual steps in the Dialogue Decision Process are:

- frame (includes problem definition, scope, criteria and time)
- develop alternatives (identify and gather information on a wide range of alternatives)
- evaluate alternatives (evaluate those alternatives directed by the decision making group against agreed criteria)
- implement

At each of these steps there is assessment work by the advisory group and decisions by the decision making group.

The Dialogue Decision Process is used in this report to compare whether different frameworks offer sufficient dialogue for best practice decision making.

What are risk assessment frameworks?

The terms 'risk assessment and 'risk analysis' are broadly equivalent, but different technical disciplines use the terms in subtly different ways that are confusing to outsiders. In some cases, risk assessment is defined as a step in the process of risk analysis[10], in others, risk analysis is defined as a step in risk assessment[11]. These distinctions are not relevant to this report, therefore the term 'risk assessment' is used throughout and it is defined as "**the process of identifying risks and describing the nature and level of risks**" [12]. Risk assessment may, or may not, contain some evaluation of options in relation to the level of risk, but it does not cover making the decision. For more discussion on the use of the terms 'risk assessment' and 'risk analysis', see the accompanying report based on interviews with decision makers.

Frameworks incorporating the word "risk" in their name – risk assessment, risk analysis and risk management frameworks – vary considerably. Some frameworks, most often those called 'risk management frameworks', have a focus on making specific risk-based decisions, and therefore fit within the category of decision frameworks. These have a model (structural component) as well as other components such as principles. An example of a risk management framework that is also a decision framework is the International Standards Organisation (ISO) standard for risk management (ISO 2018). More specific examples relevant to biosecurity include the frameworks for the international bodies concerned with food safety (Codex Alimentarius) and animal health (World Organisation for Animal Health or OIE). The OIE framework is discussed further later in this report.

In some cases, risk management frameworks give a broader view of risk management – roles and responsibilities, legislation, funding etc to manage particular kinds of risk (for example Black and Bartlett 2020). This type of framework is not a decision framework and is not considered further in this report.

Risk assessment and risk analysis frameworks have, as their end point, a conclusion about the level of risk, rather than a decision on action. Having an end point which is a conclusion about the level of risk is the defining feature of risk assessment frameworks[13].

Risk assessment frameworks can be considered as a type of decision support tool. Decision support tools are defined as "specific methods and techniques for the organisation and interrogation of data in support of planning and decision-making" (Lockie and Rockloff 2005). Tools help the decision making process, but don't contain enough components to be called a decision framework. The end

[10] For examples see the OIE and IPPC frameworks

[11] For example, see ISO 31000.

[12] This definition is equivalent to the risk identification and risk analysis steps of ISO 31000 and is consistent with the definition in the FAO Biosecurity Toolkit and with those used by the international organisations concerned with animal and plant health.

[13] There are some cases where a framework appears to have an end point which is an action, but can't really be considered a decision framework because it lacks other components of a decision framework. A well-known example is the Australian Weed Risk Assessment tool (Pheloung 1999). The end point of this tool is a numerical score that points to a particular action – either allowing a new plant species to be imported, prohibiting a plant species from import or conducting further assessment. Although the tool clearly points to a particular decision, there is no problem definition or setting of objectives, and no component of communication. Nor are there principles to guide the decision. In addition, there are other factors to be considered before making a decision on allowing a new plant species to imported into a country or region, such as how to manage any associated pests and pathogens. Because it lacks important components for making the decision, the Australian Weed Risk Assessment tool can't really be considered a decision framework as defined in this report.

point of a decision support tool can vary – it could be a level of risk, a level of priority or a particular management action – but it is not a decision. In this report, decision support tools are considered to be risk assessment frameworks if their end point is related to a level of risk.

Table 2 **Terms used in this report**

Term	Definition	Source
Decision	Choice of what should be done or which is the best of various possible actions[14]	Collins (2021)
Conclusion	A reasoned judgement	Merriam-Webster (2021a)
Decision framework	See table 1 for definitions. Decision frameworks result in a decision, that is the choice of a particular action or actions.	See table 1.
Decision model	A description of the nature of relationships between component parts of a particular decision type.	Lockie and Rockloff (2005)
Decision support tool	Specific methods and techniques for the organisation and interrogation of data in support of decision-making	Lockie and Rockloff (2005)
Risk management framework	Set of components that provide the foundations for risk management (simplified definition).	International Standards Organisation (2009)
Risk assessment	The process of identifying risks and describing the nature and level of risks	Modified from International Standards Organisation (2009)
Risk assessment framework	A set of components that provide the foundations for conclusion on the level of risk. A type of decision support tool.	Modified from International Standards Organisation (2009)

He Tangata, He Taiao, He Ōhanga

The research programme "*He Tangata, He Taiao, He Ōhanga*[15]" (Strategic Outcome 3, New Zealand's Biological Heritage National Science Challenge) aims to enable biosecurity system participants, and particularly mana whenua, to be actively engaged in the identification and prioritisation of biosecurity risks.

The overall goal of this research programme is to incorporate information from a holistic set of values into a biosecurity risk assessment framework. This framework will be one of the main outputs of the research programme. It aims to be based on the holistic values of society and culture (he tangata), the environment (he taiao), and the economy (he ōhanga). These values encompass those of kaitiakitanga, manaakitanga, whakapapa, whanaungatanga and tikanga Māori. The framework

[14] Decision and conclusion are defined in similar and sometimes overlapping ways, depending on the source. In this report, a decision is distinct from a conclusion in that a decision results in a course of action.
[15] The people, the environment, the economy

aims to be dynamic and adaptable to work at national, regional and local scales, and account for changes in biosecurity risk to NZ through external influences such as climate, trade and tourism. The research programme aims to have transformative impact in particular on the extent to which Māori voices and values are taken into account in biosecurity risk assessment.

Risk assessment and decision making in the biosecurity system – literature review

The first stage of work under *He Tangata, He Taiao, He Ōhanga* is to describe the current state of decision making based on risk assessment in the biosecurity system. This report is one of two reports that consider what frameworks are currently available and used for risk assessment and decision making, what those frameworks address, and what is missing. This report reviews the existing literature, while the other report is based on interviews with decision makers in the biosecurity system.

Methods

Search strategy for decision frameworks

The search terms used were biosecurity[16] AND decision AND framework, and biosecurity AND risk AND "management framework". All searches were conducted using both Google and Google Scholar. In some cases, sources found in the searches mentioned other decision making frameworks. These frameworks are included in the results.

Evaluation of decision frameworks

Information from the definitions and generic models discussed in the introduction has been brought together in table 3 below to describe the different components that can make up decision frameworks. The structure in table 3 is used to evaluate decision frameworks.

***Table 3* Components of decision frameworks**

Framework component	Description
Conceptual model	Theoretical basis for framework, process steps
Define the objective	At a minimum, a decision framework must contain a definition of the objective or problem. This step may also cover other details such as scope and evaluation criteria
Collect relevant information	Process step that includes collecting and analysing information, can include risk assessment
Generate feasible options	Can include evaluating options as well as identifying them
Make the decision	In order to be a decision framework, rather than a decision support tool, the framework must cover this step (for example a tool that ranks pests in a priority order but without determining what will happen as a result is not considered a decision framework).

[16] This report uses the FAO definition of biosecurity, that is a "strategic and integrated approach to analysing and managing relevant risks to human, animal and plant life and health and associated risks to the environment". Some publications use more narrow definitions of biosecurity, such as those related to managing the threat of biological terrorism or laboratory containment of organisms. Publications using these definitions were found during the searches and are counted in the number of pages assessed, but they were not included in the frameworks reviewed in detail.

Implement and evaluate	Process step following the decision, how the decision is put into action
Principles	Defined in various ways including "fundamental values" and "abstract rules applied to particular concrete instances" (Alpa 1994).
Criteria	"Standard of judgement" (Collins Dictionary 1992). Similar to principle, however principles are abstract and criteria are more specific and measurable. Keeney and Gregory (2005) define good criteria as "*unambiguous, comprehensive, direct, operational and understandable*".
Values	A value is "something (such as a principle or quality) intrinsically valuable or desirable" (Merriam Webster 2021). In this report, relates to what is affected by decisions.
Other elements	If other elements are included in the framework, they are described here.
Dialogue/ interactions	How the framework specifies any interactions should occur, including institutional arrangements and consultation.

Search strategy for risk assessment frameworks

A number of risk assessment frameworks were found during the search for decision frameworks. Additional searches were conducted in Google and Google Scholar using the search terms Biosecurity AND Risk AND Assessment AND Framework as well as Biosecurity AND Risk AND Analysis AND Framework.

There are many more frameworks that can be described as risk assessment frameworks, as opposed to decision frameworks. As an example, Roy et al. (2017) developed a series of standards for risk assessment protocols for invasive alien species, and evaluated 28 different protocols against these standards. Many of the protocols evaluated by Roy et al. (2017) could be considered to be risk assessment frameworks. Although the focus of that publication largely excluded animal and plant pests and pathogens, the protocols do relate to biosecurity.

Evaluation of risk assessment frameworks

Because of the proliferation of risk assessment frameworks, it is not feasible to list and review all that have been found. Instead, some types of frameworks are categorised and examples are given for the different categories. Particular attention has been given to the scope of the frameworks and what types of impacts are part of the framework. For example, some frameworks are focused on economic or environmental impact, while others are more holistic and look at a wider range of impacts.

Results

Decision frameworks for biosecurity

The search results for Google Scholar and Google and for the two different sets of search terms were similar, with many references returned by more than one search. The majority were not decision frameworks as defined in this report.

Table 4 **Summary of systematic search results**

Search terms	Source	Total number assessed	Comments
biosecurity AND decision AND framework	Google	176	14 looked at more closely, of which only 3 were decision frameworks.
biosecurity AND decision AND framework	Google Scholar	250	Many repeats of results found in previous search, 22 looked at more closely. One was a true decision frameworks but many were decision support tools.
biosecurity AND risk AND "management framework"	Google Scholar (Google)	120 (100)	9 were looked at more closely and one was an adaptive management framework for invasive species that was very close to being a decision framework. Google closely duplicated Google Scholar and many of the publications found had been found in the search for decision frameworks.

Five frameworks directly related to biosecurity were found that had all, or nearly all, the components of a decision making framework. These were:

1. The Biosecurity Decisions Framework[17] from the New Zealand Ministry for Primary Industries[18] (Appendix 1)
2. The risk management framework in the Food and Agriculture Organisation (FAO) Biosecurity Toolkit (FAO 2007)
3. An adaptive management framework for managing invasive species in South African national parks (Foxcroft and McGeogh 2011)
4. The World Organisation for Animal Health (OIE) Import Risk Analysis Framework
5. A framework for responding to newly detected marine species (Wotton and Hewitt 2004)

The first three of these have all the components of a decision framework, while the OIE framework and marine frameworks are both missing the "define the objective" element. This may be because both of these frameworks have very specific intended uses. The adaptive management framework didn't have "define the objective" within the framework itself, but did refer to other documents, such as vision and mission statements, and park management plans, that addressed this point.

The MPI, FAO and South African National Parks frameworks show the model as cyclical, with the results of review leading to a new definition of objectives or problems, while the OIE and marine models are linear. The South African National Parks model has communication at a defined stage in the process, through a specific forum. The other models all show communication throughout the

[17] This framework is not published as a standalone document but is appended to the response policy published here.

[18] At the time MPI (Ministry for Primary Industries) was known as MAF, or the Ministry of Agriculture and Forestry

process. This difference may reflect the geographical scale and level of impact for the decisions in the different frameworks. The South African National Parks model is aimed at decision making at the level of individual invasive species in individual parks. The other frameworks all mostly address decision making at a larger scale. The MPI framework is not specific about the type of information that is gathered in the process, but the FAO, OIE and marine frameworks all refer to risk assessment. The South African National Parks framework specifically refers to the results of monitoring programmes. These five frameworks are summarised in tables 5, 6 and 7.

Some of the frameworks found were very close to being decision frameworks, but excluded some part of the process. The most obvious of these is the Framework for Pest Risk Analysis from the International Plant Pest Convention (IPPC). The conceptual model covers all the parts expected in a decision making framework, including identification and evaluation of options, the act of making the decision and monitoring the results of that decision. However the decision and subsequent monitoring are within a box identifying them as being outside the scope of the framework. The IPPC framework is included here for comparison with the OIE Import Risk Analysis Framework (table 8).

Table 5 **Biosecurity Decision Framework and FAO Biosecurity Toolkit**

Framework component	**Biosecurity Decision Framework (2008) – see Appendix 1**	**FAO Biosecurity Toolkit (FAO 2007)**
Conceptual model	Cyclical process	Cyclical process
Define the objective	Specific questions including "what is the issue? What is our role? What are the objectives?	Preliminary risk management activities, includes activities such as identifying issues, setting goals, commissioning risk assessment.
Collect relevant information	Information gathering can occur at any step but must occur at the first step "what is the issue?"	Not addressed as a process step, however risk assessment, which is part of the framework, can be considered part of this component.
Generate feasible options	Identifying and assessing options are two steps.	Identification and selection of risk management options.
Make the decision	Making the decision also includes communicating the outcome.	Also a part of identification and selection of risk management options
Implement and evaluate	Two separate steps.	"Implementation of control measures" and "monitoring and review" are two steps in the process.
Principles	Two sets of principles, one set for the process and one for the content.	Includes principles for risk analysis and risk assessment.
Criteria	Five broad criteria for decision making: strategic fit, net benefit, feasibility, resources, opportunities/ barriers.	Doesn't include specific criteria but gives examples of the kinds of criteria that can be used.
Values	Extended principles for the framework state that "*Decisions should be driven by the objective of securing positive consequences and limiting negative consequences for our economic, social, health and environmental values*". No further guidance is given.	Discusses economic, environmental and social values with examples (see box 1 for details). Little guidance on how to assess. Notes that "*there is no consensus on how best to reflect socio-economic concerns and ecological risk assessment presents particular problems*".

Other elements	no	Guidance, including on how the framework fits with international organisations such as OIE and IPPC.
Dialogue/ interactions	Notes that consultation can occur at any stage, but in particular should happen when options are being assessed. Additional guidance identifies different levels of interaction with affected parties, from informing them to having them participate in decision making.	Risk communication principles and guidance are included, although not in the model itself.

Box 1 **Values that may be incorporated in decision-making from FAO Biosecurity Toolkit (2007)**

Values that may be incorporated in decision-making on the required level of health and life protection/acceptable level of risk:

- Economic impact (e.g. cost/benefit, cost/effectiveness)
- Social impact (e.g. recreation, lifestyle and cultural values)
- Environmental impact (e.g. native and valued introduced flora and fauna, sustainability of ecosystems and biodiversity)
- Distribution of risks and benefits amongst different stakeholder groups
- Irreversibility of impacts
- Changes in circumstance (e.g. famine, climate change, war)
- Perceptions of risk (e.g. stakeholder values and perceptions in ecological risk assessment of national parks and sanctuaries)
- Ethics and religious beliefs (e.g. in relation to cloning of animals for food)

Table 6 **Invasive species adaptive management framework and marine biosecurity framework**

Framework component	**Invasive species adaptive management framework (South African National Parks; Foxcroft and McGeogh 2011)**	**Marine biosecurity post-border management (Wotton and Hewitt 2004)**
Conceptual model	Cyclic process (specifically refers to adaptive management).	Decision tree.
Define the objective	Links to other documents that set objectives (Vision statements for national parks in general and mission statements for specific national parks, park management plans).	Not explicitly addressed. Partially addressed with "identify species" where the first action is to get a name on the newly detected organism, gather information on biology and determine whether it is a new incursion.
Collect relevant information	Monitoring programmes are the main information input, there are specific thresholds and indicators that trigger changes to management. These lead to assessment through specific science or species management fora.	Establish nature and magnitude of the problem.
Generate feasible options	Identifying management actions occurs through the fora mentioned.	Response option analysis.
Make the decision	Not clear whether the fora provide advice or make the decision.	Yes/no question on whether to undertake a response.
Implement and evaluate	Has steps for implementing the control programme and monitoring control.	Develop and implement plan, followed by monitor and review.

Principles	Refers to parks vision and mission statements and other relevant documents, but nothing specific in the framework.	Not addressed.
Criteria	Not specifically addressed.	Has a scale for describing the level of impact and some criteria that point to the kind of response approach to take.
Values	Not specifically addressed, focused on monitoring populations of the invasive species rather monitoring impacts on values.	Refers to "*healthy environment, vibrant commerce, strong communities, and high quality recreation*". An example is given of qualitative descriptors for impacts on environment but not impacts on other values.
Other elements	Refers to a wide range of supporting documents.	Has a subsequent step after "monitor and review" - prevent reinvasion.
Dialogue/ interactions	Managed through the science management forum for each park	Model has a communication plan running alongside the whole decision tree, a technical advisory group at the information gathering step, and stakeholder and community liaison prior to decision making and during implementation.

Table 7 **OIE and IPPC frameworks**

Framework component	**OIE Import Risk Analysis framework (OIE 2019)**	**IPPC risk analysis framework (IPPC 2007)**
Conceptual model	Linear process (hazard identification, risk assessment and risk management) underpinned by risk communication.	Linear process (flow chart). Steps are initiation, risk assessment and risk management.
Define the objective	Not specifically addressed. First step is hazard identification, which is identifying pathogens potentially associated with the commodity being assessed.	Initiation described as two steps. The first step is the initiation point or trigger, the second is a series of steps, determining whether an organism is a pest, defining the geographical area under consideration and reviewing any previous assessments.
Collect relevant information	Hazard identification and risk assessment both relate to this step.	Mainly covered by pest risk assessment, which is described in more detail in another document. However the framework also states that information gathering should occur throughout the process.
Generate feasible options	Option evaluation is part of risk management step in process.	Covered under the risk management step.
Make the decision	Doesn't have a specific step but covered by option evaluation. Mentions the level of risk for the pathogens, the level of risk reduction achieved by the options, and feasibility of the options.	The framework specifically states that actually making the decision is outside the process covered by the framework. Differs from the OIE framework, which does mention decision making.

Implement and evaluate	Two steps as part of risk management – implementation, and monitoring and review.	Because the framework stops just before the decision is made, this step also isn't part of the framework, however it does mention that monitoring follows making the decision.
Principles	Has principles for risk assessment, risk management and risk communication.	Refers to relevant provisions and obligations in the SPS agreement, such as non-discrimination and transparency.
Criteria	No specific criteria but principles refer to the objectives of risk management.	Not specifically addressed.
Values	Gives examples of consequences: – animal infection, disease and production losses – public health consequences. – surveillance and control costs – compensation costs – potential trade losses – adverse consequences to the environment No detail on how to assess these.	ISPM 2 refers to assessment of economic impacts, including environmental impact. ISPM 11 contains several pages of guidance on what can and can't be considered in terms of impacts and how to assess those impacts, including reference to economic analysis and non-market valuation methods.
Other elements	More detail on risk assessment steps.	Main focus is the initiation steps and, in particular, the circumstances that may trigger the process.
Dialogue/ interactions	Model has risk communication occurring at each step in the process.	Risk communication is mentioned and model has it occurring at each step in the process.

The majority of publications found through the searches did not contain decision frameworks as defined in this report. Many were decision support tools, designed to cover one part of the overall process. One such example was the framework for prioritising biosecurity risks to the dairy industry (Muellner et al. 2018). The framework prioritises different types of organism, such as animal pathogens or plant pests affecting pasture. Although the paper describing this framework was found during the search for decision frameworks, it clearly describes the framework as a tool to better understand biosecurity risks and make better decisions on allocating resources, and not as a decision making framework.

For a few of the frameworks, it wasn't clear whether they would be used as decision frameworks or decision support tools. These frameworks were written as if they were intended for use by regulatory agencies. The reason that they could be considered decision frameworks is that they end with to a decision – that is, they point to a course of action as their outcome. However, there is no component of communication, consultation or dialogue in the frameworks. It is a clear expectation of good regulatory practice that those who are affected have an opportunity to for meaningful engagement with the process (see Treasury (2017) for an example). Therefore, the frameworks may have been intended as decision support tools or as guides, rather than true decision frameworks.

An example of this kind of framework is the Principles-Based Cost-Recovery Framework for Biosecurity (Smith and Harley 2010). This framework is a decision tree for determining cost recovery in biosecurity responses. The outcome is a decision on whether cost recovery is done, how costs are recovered (fee or levy) and what type of costs (e.g. operating expenses and overheads) are recovered. There is no reference to how the industries affected by the framework are involved in the

decision (see table 8). Another example is the breeding framework for myrtle rust (Freeman et al. 2019). This framework prioritises native plants at risk from myrtle rust (*Austropuccinia psidii*) for different types of breeding approach to ensure that the plant species survive. While the outcomes of the framework are specific actions, the framework expresses these actions as recommendations, suggesting that it is intended to be a decision support tool.

A different example that is not a decision framework, but has some components, is the Pest Management Plan of Action from MPI[19] (table 8). Although this plan doesn't have a conceptual model for decision making, or a process, it does contain some parts of a decision framework, such as defining outcomes and objectives, evaluation, decision making principles and criteria, and guidance on communication and dialogue.

Table 8 **Cost-recovery framework and Pest Management Plan of Action**

Framework component	**Principles-Based Cost-Recovery Framework for Biosecurity (Smith and Harley 2010).**	**Pest Management Plan of Action (MOI 2011)**
Conceptual model	Decision tree directing to specific action depending on circumstances.	Model has three parts: "initial implementation", "pest management activity" and "improving pest management systems". Not written as a process.
Define the objective	This step is described as "identify the nature of the problem" and the goal of this step is to determine whether there is a "market failure" in relation to a particular biosecurity threat (e.g. those who are affected by a pest are not involved in the action that spreads that pest).	Intermediate and overall outcomes, and key characteristics of a good system are specifically defined. Reference to clarifying roles and goal setting.
Collect relevant information	Not described as a step in the process, but the decision tree has a series of questions to be answered, therefore information gathering to answer those questions is implicit in the process.	Not specifically included in framework
Generate feasible options	Because the framework is aimed at making a specific type of decision (how costs are shared for biosecurity responses), specific options and formulae are given.	Included under pest management planning and operations
Make the decision	Specific decisions result from applying the framework.	Included under pest management planning and operations.
Implement and evaluate	Not addressed.	Two components: "outcome and output measurement" and "measuring and analysing performance of systems".
Principles	Refers to cost recovery principles for the Australian government in another document.	Decision principles relate to the results, process and effectiveness of decision making.
Criteria	The questions in the decision tree are effectively criteria for the framework.	Key characteristics are broadly equivalent to criteria in this framework.

[19] This plan was published when MPI was still known as MAF.

Values	Focused on cost-sharing decision making and so only specific economic impacts on industries.	Pest management system outcomes are defined as “economic strength, healthy environment, healthy New Zealanders, cultural identity”. Although some further definition of these outcomes is given, and the plan suggests monitoring should be in place for these outcomes, there is no further guidance.
Other elements	Refers to institutional arrangements.	Most of the document is a plan for implementing better pest management.
Dialogue/ interactions	Not address and as a very prescriptive framework it's unclear whether there is a role for discussion and consultation.	Covered in some detail, including the identification of lead agencies for certain activities and discussion of capability building, partnerships and collective action.

Additional decision frameworks

Because so few decision frameworks were found that directly related to biosecurity, two additional frameworks that were identified during the searches have been included for comparison. Both are frameworks for resource management and are relevant to biosecurity.

The USA National Academy of Sciences framework (NAS 2013; table 9) is a general framework intended for decision making aimed at addressing “sustainability challenges”. In particular, the framework is aimed at the development of ongoing interagency projects and programmes, such as a crosscutting programme to support sustainable development in cities. As well as a conceptual model, the framework has principles and communication. It also highlights that institutional stability is important for effective decision making.

The Mauriora Systems Framework (Matunga 1993; table 9) is a framework for resource management decisions, based on te ao Māori. It is described as an iterative process based around mauri. It is a spatial framework, based on identifying the taonga potentially affected and then the tangata whenua with responsibilities as kaitiaki for those taonga.

Table 9 **National Academy of Sciences and Mauriora Systems Framework**

Framework component	**USA National Academy of Sciences (2013)**	**Mauriora Systems Framework (Matunga, 1993)**
Conceptual model	Linear process with a loop back from outcomes to framing the problem.	Iterative process around Mauri.
Define the objective	Covered in both the first and second phase of the process with elements such as "frame the problem", "identify project goals".	Identify the take (development proposition or proposal).
Collect relevant information	Covered in both the first and second phase of the process, with elements such as "identify resource connections", "identify agency linkages" and "identify information and tools needed".	Taonga and kaitiaki (identify taonga likely to be affected by the take, identify kaitiaki for the taonga who then process the proposition according to their tikanga).

Generate feasible options	Under second phase, described as "design action plan"	Ritenga (end with ritenga, (i.e., implication) of applying ngā tikanga to the take).
Make the decision	Framework effectively covers multiple decisions rather than a single large decision.	The process is described as iterative eventually leading to a decision.
Implement and evaluate	Covered by the third and fourth phase. The third phase relates to short-term outcomes and the fourth, long-term outcomes.	Not specifically addressed but implicit in the role of kaitiaki.
Principles	Refers to six principles that characterise effective decision frameworks.	Tikanga are underpinned by kaitiakitanga, manaakitanga etc, these may be considered as principles.
Criteria	A generic framework, so doesn't include any specific criteria.	Not specifically addressed.
Values	Notes that “All dimensions of the problem must be identified, including the environmental resource connections, societal connections, and economic connections” and the need to include input from “relevant parties” at this stage is mentioned. No further guidance.	Focused on the mauri of taonga, with no further guidance.
Other elements	Refers to institutional arrangements.	Taonga and kaitiaki are spatial, meaning that the framework has a spatial element.
Dialogue/ interactions	Addressed in first and second phases of framework and implicit throughout.	Dialogue/ discussion/ kōrero is implicit in the framework, as only kaitiaki can assess a proposal or risk according to their tikanga.

Risk assessment frameworks for biosecurity

In addition to the frameworks found during earlier searches, I assessed 200 pages returned by the sets of search terms given in the methods section. From these pages, 23 risk assessment frameworks were selected and are summarised in tables 10-13.

Frameworks under the Sanitary and Phytosanitary (SPS) Agreement

A number of different risk assessment frameworks relate to international trade conducted under the SPS Agreement. In the section on decision frameworks, I have described the frameworks for the OIE and IPPC. Individual countries have used the OIE and IPPC frameworks to develop their own frameworks for risk assessment. In some cases both the OIE and IPPC are covered under the one framework (Australia, New Zealand) while in others they are separate (Canada, Europe, USA). Examples of frameworks that fit under the SPS Agreement are summarised in table 10.

Table 10 **Risk assessment frameworks under SPS agreement**

Name and link	Scope of assessments	Values considered

Australian Biosecurity Import Risk Analysis Guidelines 2016 (DAWE 2016)	Imported animals, animal products, plants and plant products.	Human, animal or plant health, the environment, economic or community activities.
Canadian Food Inspection Agency Pest Risk Analysis Process (CFIA 2017)	Import requests for fruit, vegetables and plants for planting.	Not stated
European Food Safety Authority Commodity Risk Assessment guidance (Bragard et al. 2019)	High risk plants and plant products	Not stated, but a previous document refers to impacts on plant species and the environment, but excludes economic impacts
European Food Safety Authority guidance on quantitative risk assessment (Jeger et al. 2018)	Plant pests	Crop output, yield or quality. Environmental impacts in terms of ecosystem services and biodiversity levels.
European Plant Protection Organisation (EPPO)	Plant pests	Economic, environment, social
New Zealand Import Risk Analysis Process Overview (MPI 2020)	Imported animals, animal products (including aquatic), plants and plant products.	Human health, environment (including social values), economy
Tasmanian Import Risk Analysis framework (DPIPWE 2010)	Imported animals, animal products (including aquatic), plants and plant products.	Economic, environmental, human health and social values.
Imported Plant Commodity Pest Risk Assessment Framework (USDA 2020)	Plants and plant products	Economic impacts, may cover environment but not clear.

Ranking frameworks

Another set of frameworks are those that score or rank pests in various ways. Some of these have been mentioned earlier in the report as they came up in the searches for decision frameworks. Only some examples of these frameworks are given (table 11), as there are very many of them.

Table 11 **Risk assessment frameworks for ranking and prioritisation**

Name and link	Description	Scope
Australian weed risk assessment tool (Pheloung 1999)	Trait-based scoring system	Economic and environmental weeds
D-BRiEF risk prioritisation framework for dairy industry (Muellner et al. 2018)	Decision support tool based on multi-criteria decision model	Dairy industry (economic), pathogens, pests of pasture
Far North Queensland risk management and planning framework (FNQROC 2019)	Decision support tool for local councils to prioritise action on pests and pathogens	Weeds, plant pests and pathogens, invasive species, all values including economic, environmental and social/ cultural

Integrated framework to screen and target species for detailed biosecurity risk assessment (Singh et al. 2015)	Prioritisation/ ranking tool based on species distribution and traits	Plant parasitic nematodes
Risk assessment framework to predict invasive species establishment (Davidson et al. 2017)	Prioritisation/ ranking tool based on species distribution and traits	Aquatic species in USA Great Lakes.
Risk Analysis Framework for Prioritizing and Managing Biosecurity Threats (Montibeller et al. 2020)	Prioritisation/ ranking tool based on design choices and challenges	Emerging animal health threats and invasive species

Spatially explicit frameworks

A number of frameworks provide estimates of risk that are spatially explicit. Again, there are many of these so only some examples are given (table 12). In addition, there is a useful review on species distribution models that outlines the main tools that were available in 2012 (Froese 2012).

Table 12 **Spatial risk assessment frameworks**

Name and link	Description	Scope
Biosecure: a model analysis of biosecurity risk profiles (Barker et al. 2002)	Identifies potentially invaded niche for invasive species	Invasive invertebrates in natural ecosystems in New Zealand
Conceptual Risk Framework: Integrating Ecological Risk of Introduced Species with Recipient Ecosystems (Probert et al. 2020)	Uses modified natural disaster framework integrating hazard (pest) and asset (potentially affected ecosystem). Uses attributes of hazard and asset to produce maps and rankings.	Ecosystems, not specific about hazard/ pest type, New Zealand
Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica (Chown et al. 2012)	Identifies areas of Antarctica at highest risk of invasion based on propagule pressure and environmental suitability	Vascular plants, Antarctica
Integrated risk-assessment framework for multiple threats to floodplain values in the Kakadu Region (Bayliss et al. 2018)	Maps threats to natural, cultural and economic values in the park	Feral animals and aquatic weeds in Kakadu National Park as well as sea-level rise/ saltwater inundation.

Miscellaneous frameworks

Some frameworks didn't fit in to the above categories and are included here to demonstrate the diversity of frameworks developed for biosecurity risk assessment (table 13).

Table 13 **Miscellaneous risk assessment frameworks**

Name and link	Description	Scope

The Epidemiological Framework for Biological Invasions (EFBI): an interdisciplinary foundation for the assessment of biosecurity threats (Hulme et al. 2020)	Looks at invasive species through the lens of disease modelling and epidemiology by classifying ecosystems by their susceptibility	Largely theoretical, considers lakes as an example.
Risk assessment framework for emerging vector-borne livestock diseases (de Vos)	Framework for assessing likelihood of introduction, spread and persistence and impacts on animal and human health, including social and environmental impacts.	Vector-borne livestock disease in the Netherlands, Rift valley fever used as an example.
The UK risk assessment scheme for all non-native species (Baker et al. 2008)	A framework for approaching assessments from a range of different angles, such as the invasive species, pathway or recipient ecosystem.	All types of invasive species including pests of plants and animal pathogens.
Valuing biodiversity: Decision support for biosecurity response (Bell 2011)	Method for assigning economic value to ecosystems. Uses dollar values (willingness to pay) from surveys to give a value to ecosystems	Environmental and social values, not specific about hazard/ pest type

Frameworks for assessing social impacts/ holistic impacts

While searching for risk assessment frameworks, I also found some frameworks that weren't strictly risk assessment frameworks or weren't focused on biosecurity, but were relevant to the assessment of impacts on a more holistic value set.

Roy et al. (2017) provided a framework for evaluating risk and impact assessment schemes for alien invasive species. As part of that framework, they provided guidance on assessing a) impacts on biodiversity and ecosystems b) ecosystem services and c) socio-economic impacts. The last of these covered economic impacts as well as impacts on human health and well-being, and their publication included a suggested checklist for socio-economic impacts. This checklist is the most comprehensive one that I have seen for human health and well-being, and so is included in Table 14.

Table 14 **A suggested checklist of negative socio-economic impacts of invasive alien species to be considered in risk assessments, from Roy et al. (2018)**

Socio-economic impact	Description
Negative impacts on economic sectors	Negative impacts on agriculture sector
	Negative impacts on forestry sector
	Negative impacts on animal production (including fisheries and aquaculture)
	Negative impacts on tourism
Negative impact on human infrastructure	Damage to buildings (including dams, traffic and energy infrastructure)

Socio-economic impact	Description
Negative impact on human health	Injuries (including bites, stings, scratches, rashes), transmission of diseases and parasites to humans, bioaccumulation of noxious substances, health hazard due to contamination with pathogens or parasites, as well as secondary plant compounds, toxins or allergen substances such as pollen.
Negative impact on well-being and sustainable development	Noise disturbance (e.g. by parakeets), pollution of recreational areas (water bodies, rural parks, golf courses or city parks), fouling, eutrophication, damage by trampling and overgrazing, restrictions in accessibility (e.g. by thorns, other injuring structures, successional processes, or recent pesticide application) to habitats or landscapes of recreational value. Restrictions or loss of recreational activities, aesthetic attraction or touristic value. Restrictions concerning aesthetic values and natural or cultural heritage.
	Hindering local and regional sustainable development with respect to water security, food security, natural hazard mitigation, climate change mitigation and adaptation, employment.
	Hindering diversification of sustainable ~~of~~ regional development
	Hindering opportunities for education, research and innovation

Roy et al. (2017) found that around half of the risk and impact assessment protocols they evaluated considered socio-economic impacts, at least in part. However most contained relatively little detail or guidance on how to assess these impacts. The exception was Bacher et al. (2017), who developed a framework for assessing the impact of alien species on human well-being. The framework is based on the 'capability approach' to measuring well-being. This means that it considers what people are able to do and to be (their capability set), and then what they actually do (their realised activities). The main part of this framework is a set of five descriptors ranging from 'minimal concern' to 'massive', as well as a 'data deficient' category.

While this framework is intended for documenting existing impacts, it may also be useful for risk assessment, that is, predicting impacts.

Table 15 **Description of Socio-Economic Impact categories from Bacher et al. (2017)**

Impact category	Description
Minimal concern	No deleterious impacts reported despite availability of relevant studies with regard to its impact on human well-being. Taxa that have been evaluated under the SEICAT [i.e. the socio-economic impact assessment tool] process but for which impacts have not been assessed in any study should not be classified in this category, but rather should be classified as data deficient
Minor	Negative effect on peoples' well-being, such that the alien taxon makes it difficult for people to participate in their normal activities. Individual people in an activity suffer in at least one constituent of well-being (i.e. security; material and non-material assets; health; social, spiritual and cultural relations). Reductions of well-being can be detected through e.g. income loss, health problems, higher effort or expenses to participate in activities, increased difficulty in accessing goods, disruption of social activities,

	induction of fear, but no change in activity size is reported, i.e. the number of people participating in that activity remains the same
Moderate	Negative effects on well-being leading to changes in activity size, fewer people participating in an activity, but the activity is still carried out. Reductions in activity size can be due to various reasons, e.g. moving the activity to regions without the alien taxon or to other parts of the area less invaded by the alien taxon; partial abandonment of an activity without replacement by other activities; or switch to other activities while staying in the same area invaded by the alien taxon. Also, spatial displacement, abandonment or switch of activities does not increase human well-being compared to levels before the alien taxon invaded the region (no increase in opportunities due to the alien taxon)
Major	Local disappearance of an activity from all or part of the area invaded by the alien taxon. Collapse of the specific social activity, switch to other activities, or abandonment of activity without replacement, or emigration from region. Change is likely to be reversible within a decade after removal or control of the alien taxon. "Local disappearance" does not necessarily imply the disappearance of activities from the entire region assessed, but refers to the typical spatial scale over which social communities in the region are characterised (e.g. a human settlement)
Massive	Local disappearance of an activity from all or part of the area invaded by the alien taxon. Change is likely to be permanent and irreversible for at least a decade after removal of the alien taxon, due to fundamental structural changes of socio-economic community or environmental conditions ("regime shift")
Data deficient	There is no information to classify the taxon with respect to its impact, or insufficient time has elapsed since introduction for impacts to have become apparent

Outside the fields of biosecurity and invasive species, impact assessment is a discipline related to identifying the consequences of policies, programmes, plans and projects (IAIA 2021). While this kind of impact assessment is slightly different to the impact assessment done as part of a biosecurity risk assessment, they are similar enough that publications in this area are relevant to biosecurity. The International Association for Impact Assessment collates lists of key citations in the different subdisciplines of impact assessment; some of these are useful in considering holistic values in biosecurity risk assessment.

As an example, one publication from the International Association for Impact Assessment is a guidance document on assessing social impacts (Vanclay et al. 2015). It contains extensive guidance relevant to biosecurity risk assessment, including a comprehensive definition of what social impacts are, an explanation of the public participation continuum and a detailed description of the social impact assessment process.

Discussion

There are many frameworks intended to improve biosecurity decision making. Some frameworks are aimed at improving the decision process itself (decision frameworks), but the majority are intended to act as inputs to the decision process (risk assessment frameworks).

Among the decision frameworks, most are aimed at specific types of decision, and cannot be used for other decisions without modification. The adaptive management framework from Foxcroft and McGeoch (2011) is specifically for managing invasive species in South African national parks. The marine biosecurity framework is for decisions about how to manage newly-detected marine species (Wotton and Hewitt 2004). The framework developed by Smith and Harley (2010) is for decision making about cost recovery for biosecurity responses, and the Pest Management Plan of Action (MPI 2011) is for the management of established pests. These frameworks are useful as examples, but they are unlikely to find wider use in decision making.

Three frameworks were focused on international trade (the FAO Biosecurity Toolkit, the OIE (animal health) framework and the IPPC (plant health) framework). As required under the rules of international trade, these frameworks placed risk assessment as central to the decision making process. While they can't be used for other purposes, they do contain useful features. For example, the framework in the FAO Biosecurity Toolkit identifies two separate functions in the decision process – risk assessment and risk management. The guidance for this framework notes that the two work together in an iterative manner throughout the process, similar to the way that the decision board and project team work in the Dialogue Decision Process (Strategic Decisions Group in Tani and Parnell 2013). All three frameworks for international trade highlight that communication about the risks needs to occur throughout the process.

The Biosecurity Decisions Framework (MPI 2008) was the exception among the decision frameworks, because it was aimed at all kinds of biosecurity decisions and many kinds of supporting information, not just risk assessment. It is a relatively simple framework, covering three pages and with another four pages of guidance (see appendix 1). It is also one of relatively few frameworks to identify different levels of interaction with those who are affected by the decision. At one end of the continuum is informing those who are affected, at the other is having them fully participate in the decision making process.

While some of these frameworks refer to a holistic set of values, none of them provide much guidance on what exactly that might mean. The framework in the FAO Biosecurity Toolkit comes the closest, when it describes the range of values that may be incorporated in decision making (Box 1).

Risk assessment frameworks are similar to decision frameworks, in that many are intended for a specific purpose and have limited usefulness outside this purpose. For example, a number of countries have developed risk assessment frameworks for international trade (that is, fitting within the frameworks of the OIE for animal health and the IPPC for plant health). A number are ranking frameworks with different intended uses, for example assessing proposed new plant introductions to Australia (Pheloung 1999) or threats to the dairy industry (Muellner et al. 2018). Some are focused on specific geographical locations, such as Antarctica (Chown et al. 2012) or Kakadu National Park in Australia (Bayliss et al. 2018). Others, however are more general, such as Hulme et al. (2020), Montibeller et al. (2020) and Probert et al. (2018).

As with the decision frameworks, few gave any detailed consideration of a holistic set of values. While a number considered environmental impacts in more detail, only two considered social impacts. Roy et al. (2017) gave a suggested checklist for social and economic impacts of alien invasive species (table 15) and Bacher et al. (2017) identified different categories of impact on human wellbeing (table 16).

Outside the field of biosecurity, however, there is useful guidance that can help in developing frameworks for biosecurity. In particular, the guide from the International Association for Impact Assessment (Vanclay et al. 2015) is highly relevant to risk assessment and decision making for biosecurity.

Although there are existing frameworks for biosecurity decision making and risk assessment, the accompanying report, based on interviews with decision makers, suggests that these frameworks are not widely used. One reason may be the limited scope of most frameworks. For example, there are frameworks for both animal health and plant health in relation to international trade, but these frameworks can't be used for decisions on whether to respond to a new pest, or local government decisions on which pests to include in a Regional Pest Management Plan. Within the frameworks for international trade, individual countries have developed more detailed risk assessment frameworks (table 11), suggesting that frameworks need to take local circumstances into account.

The limited use of frameworks, combined with the large number available in the literature, suggest that there are barriers between the development of frameworks and their implementation. One barrier may relate to reluctance on the part of decision makers to use frameworks, despite there being many that are available. On the other hand, it may be that the frameworks that are developed don't address what decision makers actually need, so the barrier is with the frameworks themselves and not the decision makers.

Montibeller et al. (2020) provide some insight into these barriers. They suggest that design choices for risk assessments need to consider three different dimensions – not only the risk assessment tools, but the risk assessors who use those tools and the organisations that use the outputs of the risk assessments. The decisions made for each of those dimensions can affect whether or not a risk assessment is used. Their suggestion may explain why many published risk assessment frameworks don't appear to be used at all – in the majority of frameworks, the only dimension considered is the tool itself.

Conclusions

The National Science Challenge programme *He Tangata, He Taiao, He Ōhanga*, aims to incorporate information from a holistic set of values into a new biosecurity risk assessment framework, to help inform better biosecurity decisions. This literature review, with the accompanying report based on interviews with decision makers, is the first stage in that programme. The literature review considers what is already available to support risk assessment and decision making in the biosecurity system. Together, the two reports aim to identify gaps in current knowledge and tools, and to help identify the research needed to achieve the programme goals.

The results of the literature review suggest that there is an almost overwhelming number of existing risk assessment frameworks that are specifically for biosecurity. It wasn't possible to identify them all within the time available. Decision frameworks for biosecurity are less common, although there are also a number outside the field of biosecurity that are relevant.

Despite the large number of frameworks, there are still gaps. In particular, most frameworks have a narrow scope and are intended for only one kind of decision. Although there are some frameworks with a more general scope (such as the Biosecurity Decisions Framework (table 6), these don't

appear to be used much, based on the results of interviews with decision makers in the accompanying report.

There are also gaps in the way that the frameworks address a holistic set of values. The Biosecurity Decisions Framework, for example, contains the principle that "*Decisions should aim to improve New Zealand's overall economic, social, health and environmental values*" (see appendix 1). However there is no further guidance in the framework on how this should be done. Relatively few of the frameworks gave much guidance on how to address the different values, especially social values. Those that did (Roy et al. 2017, Bacher et al. 2017, Vanclay et al. 2015) may be a useful starting point for further work.

The limited use of frameworks described in the accompanying report, combined with the large numbers of frameworks published in the literature, pose a challenge for any researcher considering work on risk assessment and decision frameworks. Any new framework risks joining a list of frameworks that are published but not used for decision making. The work of Montibeller et al. (2020) suggests that developing tools is only a part of the process, and that those who use the framework, and those who use the results, also need to be considered.

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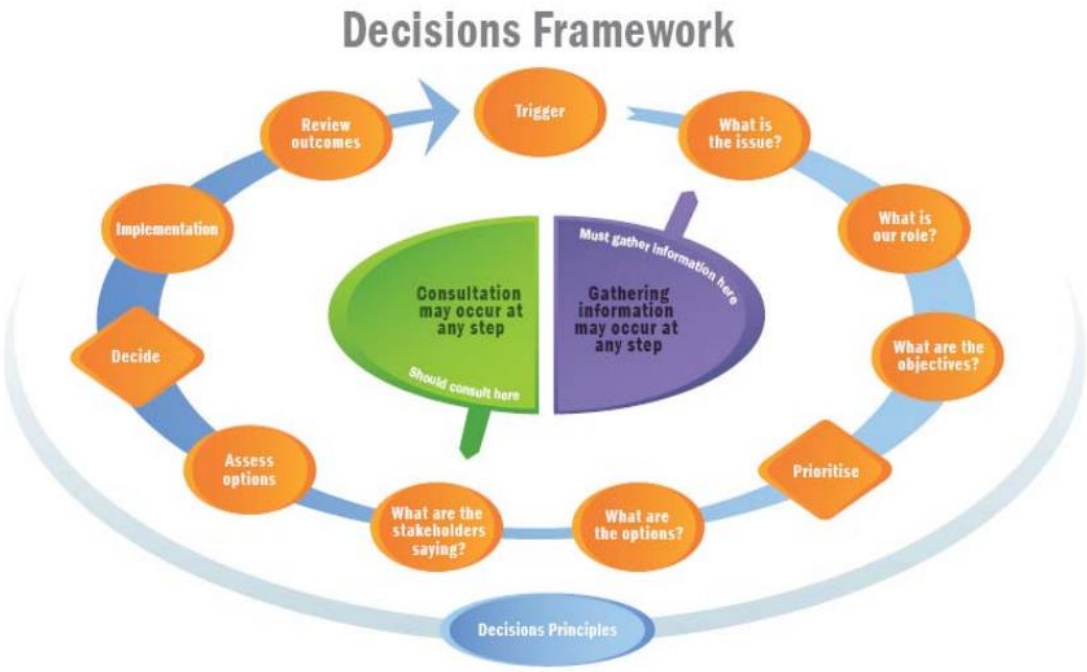
Appendix 1 – Biosecurity Decisions Framework



Biosecurity decisions-framewor

Biosecurity extended principles.