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Guide for Risk Analysis Assessing the Impacts of the Introduction of Non-Indigenous Species

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Draft Guide for risk analysis assessing the impacts of the introduction of non-indigenous species

1.0 Introduction

Our ability to manage the variety of human induced stresses in the marine environment is hampered by limited resources, a lack of fundamental knowledge and the absence of appropriate tools. This is particularly true when faced with alien species. Because of this lack of resource and data, **risk assessment** (RA) is frequently used by decision makers and management to direct actions with regards to alien.

This proposed draft guide to risk analysis draws upon information from published papers (Hewitt *et al.* 2006; Campbell and Gallagher, 2007; Campbell and Hewitt *in prep*), Australian, New Zealand, and Chilean government guidelines (Kahn *et al.* 1999; Anon 2005; Campbell 2005a, b, c; Hewitt and Campbell 2005), the ICES Code of Practice for the Introduction and Transfers of Marine Organisms (2004), and the draft IMO Guideline (G7).

In simple terms, risk assessment is used to determine the likelihood that an event may occur and what the consequences of such an event will be. Risk analysis is a component of a risk framework that identifies and assesses the risk. A risk management framework operates by establishing the context (i.e., alien species in a region; **hazard analysis**); identifying the risk, hazards and effects (i.e., impacts on **core values**); assessing the risks (analyse and evaluate the risks); and treating the risk(s) (i.e., if warranted; **incursion** response activity, **mitigation**) (e.g., Australian Risk Management Guidelines; Standards Australia 2000, 2004). A measure of risk is derived by multiplying likelihood by consequence. This process is summarised in Figure 1. Hazard analysis determines the actions, events, substances, environmental conditions, or species that could result in an undesired event. Alien species, vectors or transport pathways are all examples of hazards.

Before undertaking a risk analysis the risk endpoint must be determined. Endpoint selection will determine what type of null hypothesis is tested during the risk analysis. With alien species risk assessments, the endpoint's tend to be either: a) quarantine related – where the species has arrived and therefore barrier control has been breached resulting in a quarantine failure; or b) impact driven – where the risk assessment examines the effect/impact/harm the alien species will have as the basis of decision making. If a barrier control stance is taken, then all alien species consequences are classified as "significant" and the likelihood must be determined to derive risk. The ballast water convention approaches alien marine species from a quarantine stance, which tends to blanket all alien species as causing significant consequences when in reality this may not be the case if assessed against all core values. If the assessment is impact driven, then both the likelihood of arrival and the impact of the arrival (consequence) must be determined to derive risk. An impact approach is typically followed when determining if an incursion and its likely spread can or should be eradicated or managed. If a species is seen as causing negligible to low risk then it is likely to be monitored but no further action taken.

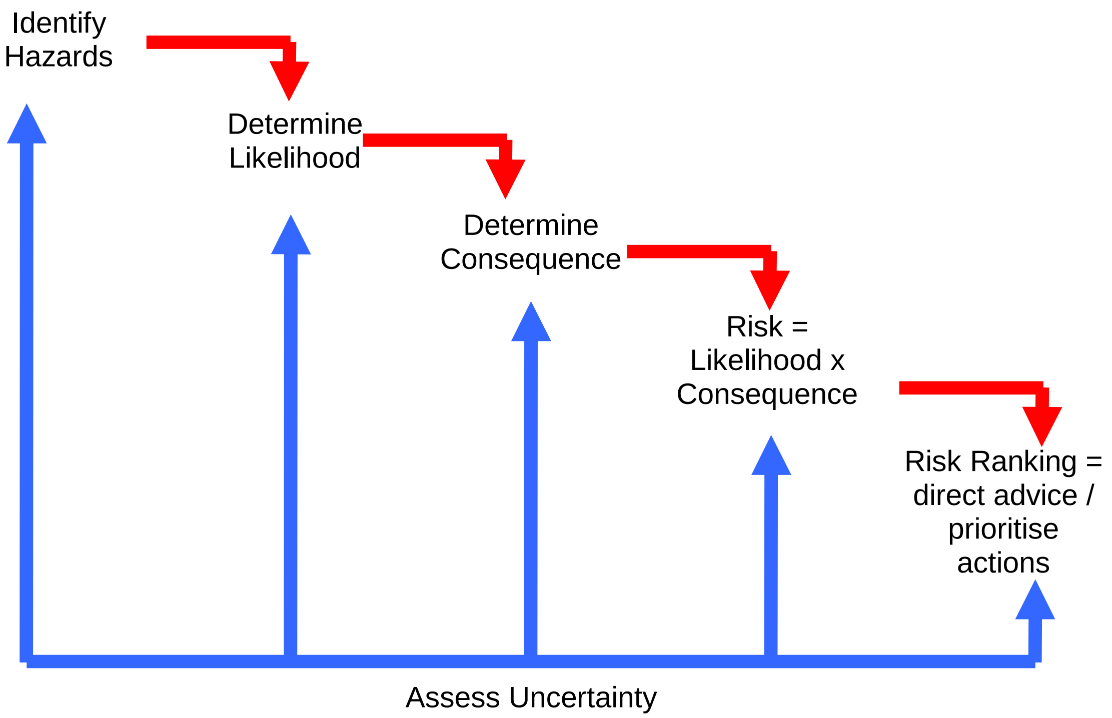

Figure 1. Risk process

To aid management in prioritising action in relation to an alien species import request or alien species incursion, the real and perceived impacts this species will have is examined against the regional core values (environment, economic, social, and cultural) in the import/incursion region and other potential regions that may be capable of sustaining the alien species. Using core values, places management action into a context of being able to objectively assess alien species across environmental and socio-political issues. The core values are:

- **Environment** – everything from the biological to physical characteristics of an ecosystem being assessed, excluding extractive (economic) use and aesthetic value. Examples include floral and faunal biodiversity, habitat, rare, endangered and protected species and marine protected areas.
- **Economics** – components within an ecosystem that provide a current or potential economic gain or loss. Examples include the infrastructure associated with ports, marinas and shipping channels, moorings and allocated mariculture and fisheries areas.
- **Social** – the values placed on a location in relation to human use for pleasure, aesthetic, generational values. This value may also include human health. Examples include tourism, family outings, learning and aesthetics.
- **Cultural** – those aspects of the marine environment that represent an iconic or spiritual value, including those that create a sense of local, regional or national identity.

Each core value consists of a variety of different subcomponents that will differ both spatially and temporally. A risk assessment can occur at the level of the core value or at the level of the core-value subcomponents. A risk analysis of the impact an alien species may have on the four core values can be determined through a six step process, as outlined in Figure 1:

Step 1: Identify Hazard(s)

Identify the species (species RA), vector (species or vector RA), transport mechanism (species or vector RA), or node (pathway RA, environmental matching) that poses the risk. These hazards may act synergistically and hence more than one type of risk of assessment may be applicable to the hazard. Several methods have been used to identify the potential hazards in preparation for qualitative or quantitative evaluations of risk. These include the collation of expert 'heuristics' (via a Delphi process), the use of hazard and operability analyses and the use of fault tree analyses.

Step 2: Determine Likelihood

Likelihood is typically described as the probability of an event (impact or incursion) occurring, ranging from rare events to likely or frequent events. Table 1 illustrates the matrix used to determine likelihood. If the event is an intentional introduction then derivations of likelihood is straightforward. If the event is unintentional then likelihood is determined based on best available information. For example, if the alien species already exists within a **bioprovince** then it is likely that it can exist within all areas of that bioprovince.

Table 1. Likelihood.

Descriptor	Description	Percentage
Rare	Event will only occur in exceptional circumstances	<5%
Unlikely	Event could occur but not expected	25%
Possible	Event could occur	50%
Likely	Event will probably occur in most circumstances	75%
Almost Certain	Event is expected to occur in most circumstances	>95%

Step 3: Determine Consequence (degree of impact/change an alien species will have)

Consequence measures the impact an alien species may have on the regional core values. Consequence can be derived by measuring the change in value from a pre- and post impacted system. Consequence matrices (examples are provided in Appendix A) are used to assess the change because each core value may react differently to change. For example, a 10% change (down turn) in the economy may have catastrophic impacts upon the impacted industry, region or country (E. Gonzalez pers. comm.). Yet, a 10% alteration in biodiversity may not be discernible from fluctuations in natural variation (e.g., Harwood and Stokes 2003). Therefore, it is important to assess change against consequence matrices that are specifically developed for each core value. The consequence matrices provide multiple examples of varying levels of impact (change), not all of which are required for that level to be considered relevant. Although monetary units are often used to measure change in value (because they are easily understood and facilitate comparison) this does not have to be the unit of measure; semi-quantitative categorical ranking (low, medium, high value) is also possible.

Step 4: Determine Risk

A measure of risk is derived by multiplying likelihood by consequence. A risk matrix is used to determine the level of risk (Table 2). Thus, for example, if the likelihood of a *Mytilopsis sallei* (black striped mussel) incursion within the Mediterranean is rare, and the consequence of such an incursion is major, then the level of risk is moderate.

The use of a risk measure is an established and valid method to represent risk posed by alien species (e.g., Kahn et al. 1999; Hewitt and Hayes 2003). A risk assessment is incomplete unless a measure of risk is calculated. Standard methods for calculating risk exist and are typically used (e.g., Fletcher *et al.* 2001; Aven 2003).

Table 2. Risk Matrix. N = negligible; L = low, M = moderate; H = high; E = extreme

	Consequence				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Significant**
Rare	N	L	L	M	M
Unlikely	N	L	M	H	H
Possible	N	L	H	H	E
Likely	N	M	H	E	E
Almost certain	N	M	E	E	E

Step 5: Determine Risk Ranking

Once a level of risk is determined management (including scientific) recommendations can be made. Recommendations may include taking no action, halting imports, use of quarantine, implementation of vector cleaning (hull fouling), use of biocontrol etc. Risk ranking should assess analysis of social and political needs, resulting in pragmatic action(s) being developed. National and international obligations play an important part in this step.

Step 6: Assess Uncertainty

This step occurs throughout the risk assessment process. Regardless of the method used, evaluations will have uncertainty surrounding the outcomes. This can be due either to measurement error or real variability in the assessment. Uncertainty exists because there is natural and stochastic variation in our environments that are difficult to capture, and humans have an incomplete understanding of the biological, physical and anthropogenic systems. This is understandable as ecosystems are highly complex and interconnected varying both spatially and temporally. It is often impossible to predict ecosystem dynamics (see Burgman *et al.* 1993; Harwood and Stokes 2003). Uncertainty also occurs when regarding acceptance criteria – what is an acceptable level of risk? Acceptable level of risk needs to be determined on a regional or country basis and will invariably draw upon high value regions, species and activities that need to be protected both temporally and spatially.

When attempting to determine impacts upon an ecosystem two approaches are often used. Both approaches identify aspects that make up an ecosystem and then assess impacts to these aspects. The first approach uses quantitative analysis to identify the direct impacts either through empirical or manipulative experiments. This approach provides accurate data yet it has serious weaknesses: it would take multiple years, cost several million dollars and the ethical limitations associated with the use of alien species for manipulative experiments may result in limited power to discern impact. Uncertainty within this approach can be tackled through HAZOP analysis, monitoring and sensitivity analyses to improve knowledge (e.g., Hayes and Hewitt 1998).

The second approach is to determine the value of a core value and the change in value when impacted by an alien species in a semi-quantitative fashion by exploring stakeholder and expert opinions and beliefs (**Delphi approach**). Delphic evaluations attempt to differentiate these uncertainty sources by increasing the sample size from which opinions are derived (number of experts), identifying *to the best of the assessor's ability* the best experts, and by using multiple questions to examine consistency in opinions. Different participants will have different levels of understanding, knowledge and perceptions; therefore how they value a core value and how they assess impact will vary. To capture this, the range of likelihood and/or consequence as perceived by the focus group participants is presented, with the variability used to represent uncertainty. A narrow range of views illustrates less uncertainty, while a greater range represents more uncertainty.

2.0 Types of Risk Assessment

The following pages identify and provide an overview of existing risk assessment approaches, outlining explicit research needs for each risk assessment type. Examples of where these types of risk assessment are being successfully applied on an international and regional basis are provided. There are three approaches outlined:

- **Species level risk assessments** that may be applied to intentional and unintentional introductions or translocations to help identify high risk alien species;
- **Vector based risk assessments** that allow for the differentiation within a vector of high risk items (e.g. vessels, pieces of gear, farms) or activities to aid management outcomes; and
- **Pathway level risk assessments** that allow for a cross comparison between different vectors or between different "**nodes**" such as ports and marinas.

2.1 Species Level Risk Assessment

Risk assessment can be applied to a variety of circumstances such as species level risk assessment for intentional introductions, or post-hoc analyses after an incursion (unintentional) has been detected (e.g., Organism Impact Assessments, Import Health Standards, ICES Code of Practice).

To undertake a species risk assessment the following information is vital:

- **propagule pressure**: that is the amount of biological material arriving into a specific location (e.g. country, state, region, port);
- the number of sites of release for the species;
- the number of introduction events; and
- to a lesser extent, the environmental tolerances of a species native distribution compared to the region being assessed (e.g., Mediterranean or node).

2.1.1 Examples

The ICES Code of Practice for the Introduction and Transfers of Marine Organisms (2004) is an example of a procedural methodology that incorporates the risk assessment and decision making process for intentional introductions. The ICES Code evaluates on the basis of individual planned species movements, with the intent to identify whether the target species is likely to cause harm, and whether any associated species living in, on, or with the target are likely to cause harm, including parasites, disease agents, and human pathogens. The ICES Code is a useful tool for intentional introductions.

Three common methods employed to assess a species risk in both intentional and unintentional situations the development of Import Health Standards (for intentional importation of species) and Organism Impact Assessments (OIA; for post-hoc assessments of incursions; Campbell 2005a), and the development of a next pest list (Hewitt and Hayes 2001; Hayes and Sliwa 2003).

Next Pest Lists: Identification of species of concern is a difficult and often controversial task. Nonetheless, several countries have adopted a target species approach to marine biosecurity (eg Australia, New Zealand). This approach generates target species that are "black-listed" and hence are unable to be imported into a country (through import health standards) unless an exemption is granted, or the species are identified as "unwanted organisms".

Development of next species lists rely on evaluating species against set-criteria. The criteria provide an explicit, transparent and non-discriminatory method for evaluating and identifying potential species hazards. One possible set of criteria (based on hull fouling and ballast water) are:

- The species has been reported in a shipping vector or has a ship-mediated history; AND
- The vector still exists; AND
- The species has been responsible for environmental and/or economic harms; AND
- The species is introduced to *[country/region]* or present in *[country/region]* but subject to official control (i.e., listed, restricted or otherwise legislated by an authorised national authority) (Hewitt and Hayes 2001).

Organism Impact Assessments: An organism impact assessment (OIA) evaluates species risk using an endpoint of impact: does or will the introduction of the species cause an impact on the core values (environment, economic, social, cultural). OIA's are used to evaluate unintentional incursions of alien species (e.g., Campbell 2005a). This method uses heuristic knowledge drawn from the literature and from expert panels/technical advisory groups and is similar to a 'relative risk assessment' (see Roberts et al. 2002). If there is a paucity of published, empirical scientific data on the impacts of a particular alien species a Delphi approach is adopted. The delphic approach utilises a number of focus groups from different regions, with focus group membership drawn from a range of stakeholder interest, thus representing a wide range of community perceptions. A delphic approach creates a statistical population of beliefs that captures a wide range of community opinions with the central tendency (average) being the perceived risk. Thus, the focus groups aim to assess perceived value of a recipient area and then assess the perceived impacts to this value if an alien species incursion occurs in that region. The data collected from these focus groups is then analysed and a risk assessment of the alien species impact on the four core values is determined. The OIA is undertaken in a five-six step process:

- <u>Identify the Hazard</u>
    - <u>Identify Core Value Subcomponents</u>: Each core value consists of a number of subcomponents that are broad ranging and will differ with perceptions between stakeholders. Subcomponents will also vary spatially (from region to region) and temporally (through time). Examples of core value subcomponents for the environment include habitat, protected species, biodiversity etc; for economics port infrastructure, marinas and shipping channels, fisheries; for social human health, tourism, aesthetics; and cultural spirituality, local, regional, national identity, iconic landmarks. Because of the variation in subcomponents, it is important to update risk assessments regularly.
    - <u>Value Identified Subcomponents</u>: Using contingent valuing, a dollar value or a semi-quantitative categorical ranking (low, medium, high value) associated with each core value and/or its subcomponents are assigned. Appendix B provides a brief description of valuation and its assertion; focussing on contingent valuation methods (CVM).

- <u>Determine Likelihood</u>: Likelihood is typically described as the probability of an event occurring, ranging from rare events to likely or frequent events.

- <u>Determine Consequence (degree of impact the alien species will have on each subcomponent):</u> Consequence, measures the impact the alien species may have on the core values. It is assessed by determining the change in the value of a recipient region with the alien species (see example in Appendix C), then measuring this change against a number of consequence matrices. Thus, consequence is derived by measuring the change in value from a pre- to a post impacted system. The consequence matrices provide multiple examples of varying levels of impact, not all of which are required for that level to be considered relevant. Consequences can be assessed in dollar values or by a semi-quantitative categorical ranking (see Appendix B).

- Determine Risk: A measure of risk is then derived by multiplying likelihood by consequence (Table 2).

- Assess Uncertainty: Regardless of the method used, evaluations will have uncertainty surrounding the outcomes. This can be due to measurement error or real variability in the assessment. Delphic evaluations attempt to differentiate these uncertainty sources by increasing the sample size from which opinions are derived (number of experts), identifying *to the best of the assessor's ability* the best experts, and by using multiple questions to examine consistency in opinions. Different participants will have different levels of understanding, knowledge and perceptions, therefore how they value a core value (or subcomponents) and how they assess impact will vary. To capture this, the range of likelihood and/or consequence as perceived by the focus group participants is presented, with the variability used to represent uncertainty. A narrow range of views illustrates less uncertainty, while a greater range represents more uncertainty.

To a certain extent an OIA is subjective and imprecise; however it does have strong inherent advantages such as: the ability to produce a result when empirical data is insufficient or lacking; stakeholder input across a range of regions leading to high stakeholder understanding and buy-in; transparency and education (data on alien species and effects is provided to stakeholders); and stakeholder participation by providing perceived risk.

Import Health Standards (IHS): IHS's are legislative procedural documents that are established to ensure that internationally agreed standard of quarantine and scientific evaluation are met to reduce the unwarranted restrictions of trade when importing goods. In this context, an Import Health Standard (IHS) is used to assess risk associated with intentional introductions of species (Anon 2005). Because the species being imported is intentional, then the likelihood is assessed as 'almost likely', with the consequences of such an incursion being assessed. IHS are similar to the ICES Code of Practice, combining both risk assessment and the decision making process for intentional introductions.

When a request for an importation of a species (native and alien) is received, it initiates a series of steps that lead to both risk analyses and risk assessment being undertaken. The risk assessment end point is to assess what impact this species will have on the core values of the recipient region. Most IHS assessments are species-specific; assessing the individual species and its possible associated species, however some are vector based (see later). For example, a request to import adult oysters for aquaculture purposes would involve a risk analysis of the oyster species itself, and risk analyses of all possible epi- and endo-biont associated species known from the donor region. This would then involve overlaying the risk analysis outcomes with social, economic and cultural imperatives to provide a risk assessment. Both positive and negative impacts are assessed in the risk assessment process. Typically, low to negligible risk species are granted approval for importation, with moderate to extreme risk species being rejected. However, moderate to extreme risk species can be granted importation approval (though exemption) if quarantine/containment standards are applied, met, monitored and reported upon.

The outcome of the IHS and its associated analyses is a list of species ('white' list) that is appended to the IHS document. The white list contains negligible to low risk species that have been assessed and approved for importation. Once added to the white list a species is granted future importation approval, which allows the rigour of the risk analysis, risk assessment and importation process to be bypassed. Hence, the white list becomes the first reference point for an IHS analysis when new import/export requests are made: allowing decision makers to short-circuit the process and grant exemptions without undergoing the full IHS process. To be effective the IHS document and its associated white list of exempted species need to be regularly re-evaluated, especially when new information becomes available. Two examples of IHS documents are the *Australian Import Risk Analysis for Live Ornamental Finfish* (Kahn et al. 1999) and the *New Zealand Import Health Standard for the Importation Into New Zealand of Ornamental Fish and Marine Invertebrates from All Countries* (Anon 2005).

2.2 Vector Based Risk Assessment

Vector based risk assessments identify which shipments or potential incursions are more risky than others (e.g., ballast water risk assessment undertaken in Australia). There are a large number of vectors that are known to be responsible for the transfer of marine alien species. Typically, the examples of ballast water and associated sediments, hull fouling and mariculture (aquaculture) have been concentrated upon.

The most widely established vector based risk assessments have been applied to the management of ballast water and sediments. These assessments have been performed by a number of countries and organisations, and have been based on two primary types of assessment: **environmental matching** where two environments are compared for similarity (or dissimilarity) across a range of environmental variables believed to have ecological significance; and **species based assessments** where a chain-of-events model is used to determine the likelihood of a species arriving and establishing in the receiving environment. Both types of vector based risk assessments can be applied at varying geographic scales, such as at the bioprovince (such as the Mediterranean) down to smaller regions (eg nation, state, marine protected area).

Environmental matching typically evaluates similarity in a statistical sense, with no biological determinant of the cut-off between similar and dissimilar. Similarly, the selection of environmental parameters for evaluation is rarely based on species' requirements for survival, but instead are readily accessible environmental characteristics of the **donor** and **recipient regions**. As a result, while environmental matching assessments have a reduced data requirement, they typically result in less conservative outcomes with greater likelihood of Type I error (finding a difference where none exists resulting in an erroneous low risk).

In contrast, species based risk assessments rely on detailed knowledge of the species' distributions, reproductive periodicity, physiological constraints and environmental preferences. Species level risk assessments have a high data requirement, and typically result in overly conservative outcomes with greater likelihood of Type II error (finding no difference where one exists resulting in an erroneous high risk).

The International Convention on the Management and Control of Ships Ballast Water and Sediments has identified a Risk Assessment Guideline (G7) that will underpin the ability of a State to grant exemptions from the obligations of the Convention. The current formulation of G7 (to be debated at MEPC 55) develops a framework in which both environmental matching and species based assessments are used.

Environmental matching risk assessments should be used only in circumstances where the environments are at biological extremes, such as between wholly freshwater and wholly marine environments. In these circumstances, those species that can survive at both extremes (such as **catadromous** and **anadromous** species) should be individually assessed.

In contrast, species based assessments should only be used within a single bioprovince (such as the Mediterranean) where the assumption that the majority of native species are shared. In these circumstances, the unknown species can be assumed to be native reducing the number of species assessments required. For donor ports, alien species known to cause harm should be assessed for the ability to establish and cause harm in the recipient port (and adjacent localities). Harm should be assessed according to specific impact on core values and resources. Species based assessments need to be reviewed regularly because newly available information may alter the risk analysis outcomes.

2.2.1 Examples

The development of import health standards (IHS) such as the New Zealand Import Health Standard for the Importation of Ballast Water (Biosecurity New Zealand), and the Chilean Aquaculture Species Import Process are examples of risk analyses that evaluate vector risks.

Import Health Standards: As previously stated; IHS's are legislative procedural documents that are established to ensure that internationally agreed standard of quarantine and scientific evaluation are met to reduce the unwarranted restrictions of trade. They combine both risk assessment and the decision making process to assess intentional introductions (like the ICES Code of Practice). They work by investigating the validity and risk posed by all requests to import a species (and its possible associated species) or a vector. When undertaking an IHS style assessments the likelihood of the species or vector arriving is considered to be 'almost certain', with the consequence (impact) of the species or vector being investigated. Typically, IHS applies to species however there are specific IHS's that apply to vectors. These vectors include ballast water, fishing equipment, marine rock (including live rock from the aquarium trade), imported recreational vessels, ropes and anchors. Vector based IHS's are used for regulatory purposes and when the consequence has been demonstrated. They provide action to mitigate the likelihood by providing information such as where ballast water exchange can occur, quarantine, cleaning and dumping standards, etc. Such IHS's follow the same procedures as stated previously with the exception that the emphasis of the analysis is placed on the vector itself, not upon a species. A current example of a vector IHS is the ballast water exchange at sea requirement.

Aquaculture Species Import Model: Mariculture and aquaculture are growing global industries that are attempting to address the problem of expanding populations and decreasing fish stocks. A number of regions have decided that food security can be improved by utilising alien marine species to either: a) aid in providing food to the regions population, or b) aid in providing an export product that is highly valued elsewhere and therefore marketable. Both of these reasons have merit, with the ethical use of alien marine species needing to be considered against the social and economic security that such a use may provide. Few models exist that specifically target alien species importation for aquaculture/mariculture purposes. The following model is one that has been adopted in Chile, South America, and has operated reasonably successfully (Campbell 2005b; Campbell and Hewitt 2005; Hewitt *et al.* 2006).

The model is initiated when a request to import a non-indigenous species or non-indigenous genome occurs. The request is made using standardised templates, thus allowing a transparent assessment process. At a minimum, the request should include information that allows the decision makers to determine:

- Species:
  - The species and associated species involved in the request;
  - Known impacts of the target species has had elsewhere, if any;
  - What the species will be used for;
  - Can a local species be used instead;
  - Will this species require the importation of a specific food source that is also alien (e.g., certain abalone grow better with *Macrocystis* sp as a food source);
- Export Facilities:
  - Where is the importation from (bioprovince, water temperature, salinity, disease information);
  - Certification and quarantine procedures followed by the exporting region;
  - How the importation will occur (specify whether it is importation of larvae, eggs, juveniles, adults; what measures will be taken to reduce fouling of adults; what practices are used to detect disease);
  - Are the imported stock from wild stocks, mariculture/aquaculture facilities;
  - Are the imported stock genetically modified or been fed with genetically modified food source;
- Import Facility:
  - Who is making the request (person, company, local, regional, national, international);
  - The containment and quarantine procedures that will be followed (if these need to be established, how will they be peer reviewed);
  - Does the facility meet regional/national/international certification;
  - Information about the recipient aquaculture facility (is it an open or closed facility; filtration systems used; does translocation of species between facilities occur);
  - Is there any likely release of material into the marine environment;
  - What emergency containment procedures exist;
  - What contingencies exist for disease outbreak containment within the facility;
  - Are there any requirements for the transfer of species between facilities within the country (e.g., establishing a brood stock facility);
  - The proximity of the facility to high value areas, specifically those protected by national or international obligations;
- Monitoring
  - What type of environmental health monitoring will be established;
  - What type of environmental monitoring will occur;
  - What is the frequency of monitoring;
  - Is the monitoring peer reviewed and provided to a statutory body for assessment; and
  - What provisions (contingency measures) exist if an accidental release of the alien species occurs.

It is the role of the decision makers to undertake a risk analysis and risk assessment. To be efficacious the risk process needs to define what impacts are unacceptable, what methods will be used for the risk assessments, set an acceptable level of risk, establish a scientific overview and review committee and develop contingency/action plans or guidelines to deal with the accidental release of a non-indigenous species (Figure 2). The core values (and/or the subcomponents) that the decision makers are attempting to protect and manage must be identified a priori. This can occur through a simple evaluation of national and international obligations (e.g., CBD), or it can be as complex as evaluations of individual subcomponents of the core values. In order to have a consistent process it’s ideal to identify the core values a priori, instead of identifying core values with each solicitation.

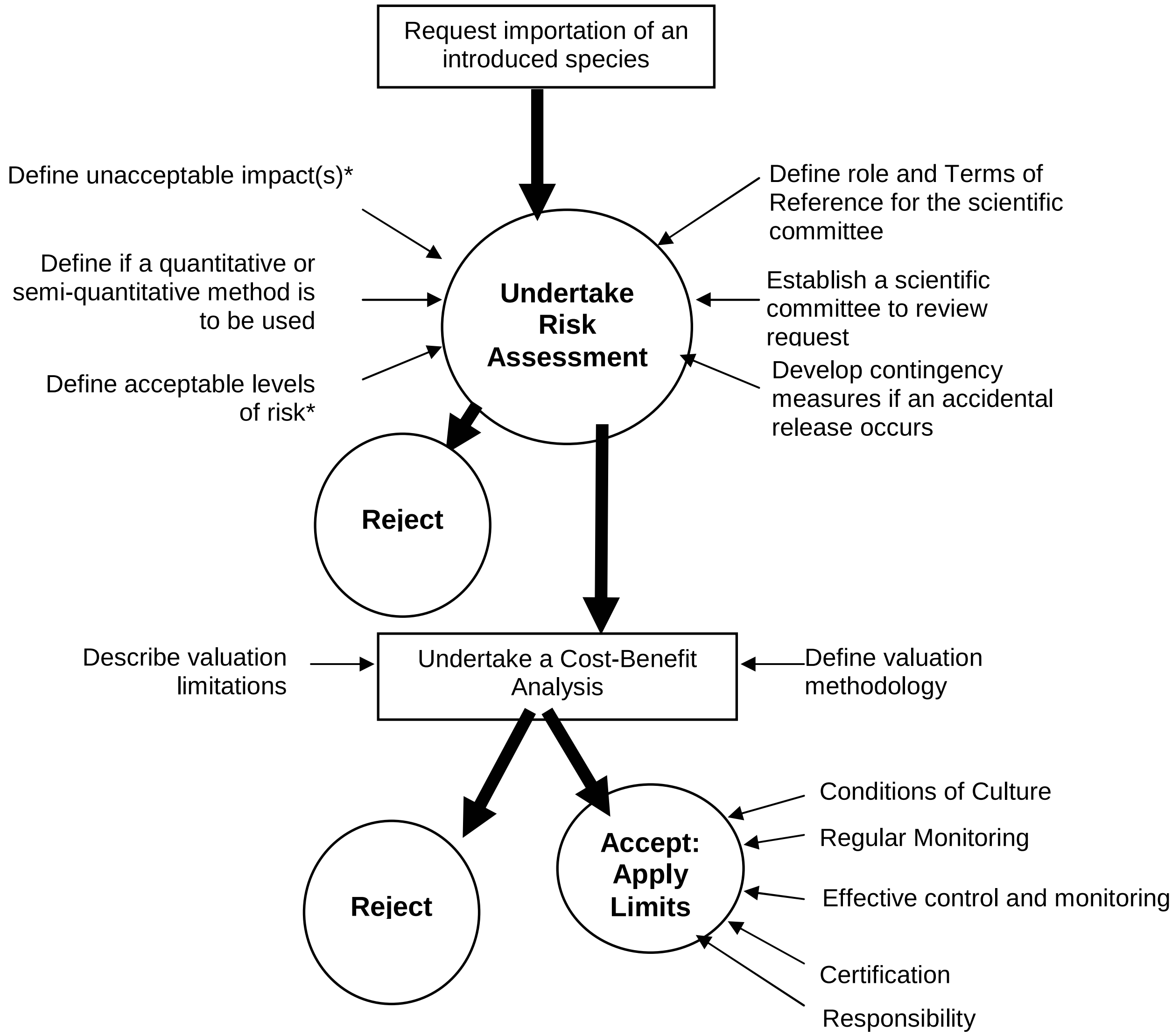

Figure 2. Conceptual risk framework for importation of non-indigenous species for aquaculture purposes (modified from A. Brown, pers. comm.) denotes actions that can occur *a priori* to the risk assessment.

In some instances, it may be necessary to conduct experimental trials with a species to determine its ability to survive, grow and be controlled in certain conditions. To ensure that all relevant data is included in the risk assessment, the risk assessment process is delayed until all experimental trial phase results are completed and assessed. Typically, trials are conducted in the donor country (risk minimisation) but if stringent quarantine procedures are stipulated and enforced, then trials can occur in the recipient country. Trials within a recipient country are never conducted in an open or semi-open environment; all materials associated with the trials (including the test species) need to be sterilised to render them harmless before disposal and there is no disposal of materials into marine or estuarine environments.

Once the risk assessment is complete the decision maker is able to determine if an application is rejected or moves into the second phase of the model. Applications that are rejected are provided with feedback, allowing for modifications and potential reapplication. If risk is considered negligible to low then a cost-benefit is performed. A cost-benefit analysis will determine the net benefits of an non-indigenous species to the ecosystem, economy, socially and culturally, and assess the costs associated with the non-indigenous species incursion (e.g., destruction of infrastructure, loss of jobs, loss of industry, loss of marine resources, extinction of species, etc). To ensure a consistent approach across all solicitations the valuation methodology and limitations must be stated *a priori* to the cost-benefit analysis. Based on the outcomes of the cost-benefit analysis a decision is made whether to reject the request for import or accept the request. Acceptance requires caveats to be stated and complied with, such as defining and regulating the conditions of culture; regulating how the species are imported (larvae/eggs, juveniles, adults); development and enforcement of regular monitoring using scientifically based methods; establishment of effective control and monitoring programs; establishment of a certification program for importers; and defined lines of responsibility to ensure transparency and to reduce potential confusion of roles should accidental release occur.

Microalgae Import Decision Tree Model: A second model that can be used in conjunction with IHS procedures is a decision-tree that leads the decision maker through a series of questions with "if/then" statements to direct actions regarding whether to approve an importation of microalgae (native, and non-indigenous species) (Campbell 2004). By answering a series of simple yes/no questions the decision-tree progress through the process indicating where importation should be rejected, approved with stipulations or approved without stipulations. The model can be qualitative, semi-quantitative or quantitative and is driven by the data input. As with IHS procedures, likelihood is almost certain since the species is being imported. Each step is assessed against a risk mitigation context (such as a management procedure) with the endpoint derived by the questions asked at each step in the process. Decision tree models invariably consider specific national and international obligations. In New Zealand, an 8-step model was developed for the importation of microalgae typically used for laboratory purposes (colour standards) and aquaculture feed that is released directly into the marine environment (Campbell 2004). Such models are readily adaptable to other countries or regions, such as the Mediterranean, and taxa (such as fish and invertebrates).

One strength of the decision tree model is the ability to incorporate multi-level analyses that deal with alien species and genetically modified organisms. A further strength is that this model combines biological and social information, as well as legal obligations, into clear instructions for decision makers.

Other Research: Further research that will feed into vector risk analyses include assessing fisheries activities and the risk these activities pose via either entraining or translocating "pest" species (N. Parker, pers. comm.). Such studies provide hazard information (e.g., vector movements by fishery, vessel type, time, origin, destination) that feeds into the development of guidelines. It is envisaged that education about the problem of translocation via fishing and aquaculture methods, coupled with consultation will be required for the guidelines to be truly effective. Domestic or regional shipping as a vector should also be investigated, with the aim that best practice guidelines are developed that provide preventative advice for recreational vessel owners to avoid translocating marine pest species.

2.3 Pathway Risk Assessment

Pathway risk assessments assess species and vectors and their intersection/overlaps (e.g., Australia, New Zealand system being developed, GloBallast assessment). Typically, this method concentrates on nodes such as ports or marina's and examines which nodes are more likely to receive a new organisms. This is determined by analysis of the number of trading regions the node is exposed to, the amount of ballast water, hull fouling, mariculture received, and the number of vessel visits.

2.3.1 Examples

Hull Fouling and Pathways: To fully capture the risk associated with hull fouling (or other vectors) requires robust, empirically derived data. The following example from New Zealand illustrates how a pathway analysis can be used to determine risk. Currently in New Zealand, a 3-year study is underway to determine the realised risk associated with hull fouling (via vector and pathway analyses). This research is readily applicable to the Mediterranean. This research examines the extent of fouling and fouling species identity on the hulls of arriving international vessels. Categories of vessels being examined are: fishing, passenger, merchant, slow-moving barges, oil platforms, and recreational vessels. The research investigates seasonal trends (winter, summer, spring and autumn) in vessel fouling for each vessel type, associated trade routes and target source/donor regions (IUCN bioregions) based on *a priori* analyses of previous shipping (merchant and recreational) and customs data. This type of research is data and effort intensive but surprisingly inexpensive (NZ$<3 million) considering the detailed data that is generated and the multiplicity of this data's uses.

This type of research collects information that allows realised risk to be assessed and hence the realised hazard (ship type and/or pathway) to be detected within all ports and marinas dealing with international vessels within a country/regions waters. This in turn greatly improves the ability of decision makers in the development of alien marine species guidelines and standards.

Nodal Analysis: Nodal analyses aim to examine the strength of different vectors (hull fouling – commercial and recreational, ballast water, and aquaculture) into specific nodes (such as ports, marinas, protected areas etc). The nodal analysis investigates donor/recipient interactions and likely flow-on-effects. This type of analysis is currently being undertaken in Australia.

Single Vector Pathway Analysis: One component of Globallast risk assessment is a pathway analysis. In this instance, the GloBallast risk assessment concentrates on a single vector, examining the relative strength of ballast water between various source ports and receiving ports. These analyses were implemented for the six GloBallast ports in Brazil, China, India, Iran, South Africa and the Ukraine. They provide a simplified analysis of risk posed by ballast water in six ports and are coupled with the GloBallast environmental matching exercise to aid in the recommendation of management strategies for ballast water management between ports.

3.0 Definitions

Term	Definition
Anadromous species	Species that spawn in freshwater environments but spend at least part of their adult life in a marine environment
Bioprovince	A large natural region defined by physiographic and biologic characteristics within which the animal and plant species show a high degree of similarity. There are no sharp and absolute boundaries but rather more or less clearly expressed transition zones. Boundaries between biological provinces overlap
Catadromous species	Species that spawn in marine environments but spend at least part of their adult life in a freshwater environment
Core Value	Biosecurity aims to deliver management outcomes to four important components of society: environment, economics, social and cultural
Delphi(c) Approach	The use of formalised groups to seek advice or to extract heuristic and experiential information. Group membership may be general (general public) or technical (i.e., scientists, decision makers, conservationists). This approach is typically used when empirical data is lacking in the published literature however a problem needs to be addressed and therefore ‘experts’ are called upon to provide advice, this advice can then be assessed against the core values, or the advice may pertain to valuation of core values
Donor Port/Region	Port or location where the alien species is taken onboard or vector originates from
Environmental Matching	The comparison of environmental similarity between two regions (donor and recipient regions) as a surrogate measure of bioinvasion risk
Hazard Analysis	Determining the actions or events that could result in an undesired event, or identifying a substances or species propensity for risk
HAZOP Analysis	Computer program that examines uncertainty in risk analysis
Incursion	The detection of an alien species in a region
Mitigation	The action to alleviate or compensate for impacts caused by an event (e.g., eradication of an introduce species). Often occurs as a Risk Management action.
Node	Port, marina, marine protected area, PSSA etc
Pathway RA	Identified species and vectors and their intersection/overlaps
Precautionary Approach (Principle)	“preventative action must be taken when there is reason to believe that harm is likely to be caused, even when there is no conclusive evidence to link cause with effect” (Eduljee 2000)
Propagule Pressure	Number of individuals released
Recipient Port/Region	Port or location where the alien species is released onboard or vector terminates travel
Risk Assessment	The means to determine the likelihood of an undesired event occurring and the consequences of such events
Species Based Assessment	Provides information about the particular risk of a nominated species
Species Risk Assessment	Identifies which species are more risky than others
Uncertainty	Confidence associated with risk assessment and/or data
Vector	Any living or non-living carrier that transports living organisms intentionally or unintentionally
Vector Risk Assessment	Identifies which shipments or potential incursions are more risky than others

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Appendix A: Generic Example of Consequence Matrices for Alien Species (from Campbell 2005a, 2005b; Hewitt and Campbell 2005)

The generic consequence matrices are identical for all alien species. Tailoring to individual alien species or regions occurs by altering the percentage values and recovery times through a process of expert advice/consultation.

Table A1. Consequence matrix: Environment – Biodiversity

Level	Descriptor	Biodiversity Impacts
1	Insignificant	• Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction is minimal (<10%) compared to loss from other human-mediated activities. • Reductions in species richness and composition are not readily detectable (<10% variation). • If the alien species was removed, recovery is expected in days; no change in species richness or composition.
2	Minor	• Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction is <20% compared to loss from other human-mediated activities. • Reductions in species richness and composition are not readily detectable (<20%). • Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction and area of alien species impact is small compared to known areas of distribution (<20%) • If the alien species was removed, recovery is expected in days to months; no loss of species (non-commercial species, non-habitat forming species and unprotected species) populations; no local extinctions.
3	Moderate	• Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction is <30% compared to loss from other human-mediated activities. • Reductions in species richness and composition are <30%. • Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction and area of alien species impact is moderate compared to known area of distribution (<30%) • If the alien species was removed, recovery is expected in less than a year; loss of at least one species (non-commercial species, non-habitat forming species and unprotected species) or populations; local extinction events.
4	Major	• Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction is <70% compared to loss from other human-mediated activities. • Reductions in species richness and composition are <70%. • Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction and area of alien species impact is small compared to known area of distribution (<70%); likely to cause local extinction. • If the alien species was removed, recovery is expected in less than a decade; loss several species (non-commercial species, non-habitat forming species and unprotected species) or populations; multiple local extinction events; one regional extinction.
5	Significant	• Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction is >70% compared to loss from other human-mediated activities; • Reductions in species richness and composition are >70%. • Biodiversity (non-commercial species, non-habitat forming species and unprotected species) reduction and area of alien species impact is small compared to known area of distribution (>70%); likely to cause local extinction. • If the alien species was removed, recovery is not expected; loss of multiple species of populations of non-commercial species, non-habitat forming species and unprotected species causing significant local extinctions; global extinction of at least one species.

Table A2. Consequence matrix: Environment – Habitat

Level	Descriptor	Habitat Impact
1	Insignificant	• No significant changes to habitat types observed; populations of habitat forming species are not affected (<1% change); alien species impacts affecting <1% of area of each habitat type. • Changes in habitat not measurable against background variability; recovery is expected in days.
2	Minor	• Localised affects on habitat in <10% of total habitat area; measurable changes to habitat types, measurable changes to habitat types, new habitat type observed; <10% reduction in population abundances of habitat forming species. • If the alien species was removed, recovery is expected in days to months; no loss of habitat-forming species populations.
3	Moderate	• <30% of habitat area affected/removed; moderate changes to habitat types, new habitat type(s) observed, possible loss of habitat type; <30% reduction in population abundances of habitat forming species. • If the alien species was removed, recovery is expected in less than 1 year; no loss of habitat-forming species.
4	Major	• <70% of habitat area affected/removed; major changes to habitat types, new habitat types observed, loss of most pre-existing habitat types; <70% reduction in population abundances of habitat forming species; local extinction of at least one habitat forming species. • If the alien species was removed, recovery is expected in less than a decade; loss of habitat types and habitat-forming species; local extinction events.
5	Significant	• >70% of habitat area affected/removed; significant changes to habitat types, no pre-existing habitat types existing; >70% reduction in population abundances of habitat forming species; local extinction of more than one habitat forming species, global extinction of one habitat forming species • If the alien species was removed, recovery is not expected; loss of multiple habitat types and habitat forming species populations causing significant local extinction; global extinction of at least one species.

Table A3. Consequence matrix: Environment - Protected Species

Level	Descriptor	Protected Species Impact
1	Insignificant	• No protected species affected due to alien species; impacts on behaviour not detectable. • In the absence of further impact, recovery is expected in days; no loss of protected species individuals.
2	Minor	• Protected species reduction due to alien species impacts is <1% compared to total human-mediated reduction. • Reductions in protected species population abundances are <1%. • If the alien species was removed, recovery is expected in days to months; no loss of non-target species populations.
3	Moderate	• Protected species reduction due to alien species impacts is <10% compared to total human-mediated reduction. • Reductions in non-target species population abundances are <10%. • If the alien species was removed, recovery is expected in less than a year; no loss of non-target species populations; potential loss of genetic diversity.
4	Major	• Protected species reduction due to alien species impacts is <20% compared to total human-mediated reduction. • Reductions in protected species population abundances are <20%. • If the alien species was removed, recovery is expected in less than a decade; loss of protected species populations causing local extinction; measurable loss of genetic diversity.
5	Significant	• Protected species reduction due to alien species impacts is >20% compared total human-mediated reduction; • Reductions in protected species population abundances are significant >20%. • If the alien species was removed, recovery is not expected; loss of protected species populations causing global extinction; local extinction of multiple protected species; significant loss of genetic diversity of multiple protected species.

Table A4. Consequence matrix: Environment - Trophic Interactions

Level	Descriptor	Trophic Interactions Impact
1	Insignificant	• No significant changes trophic level species composition observed; no change in relative abundance of trophic levels (based on biomass). • Changes in trophic interactions not measurable against background variability; recovery is expected in days.
2	Minor	• Minor changes (<10%) in relative abundance of trophic levels (based on biomass); <10% reduction of population abundances for top predator species. • If the alien species was removed, recovery is expected in days to months; no loss of keystone species populations.
3	Moderate	• Measurable changes (<30%) in relative abundance of trophic levels (based on biomass); <30% reduction of population abundances for top predator species. • If the alien species was removed, recovery is expected in less than a year; loss of keystone species populations; no loss of primary producer populations.
4	Major	• Major changes (<70%) in relative abundance of trophic levels (based on biomass); <70% reduction of population abundances for top predator species; <30% reduction of population abundances for primary producer species. • If the alien species was removed, recovery is expected in less than a decade; loss of keystone species populations; changes in trophic levels; loss of primary producer populations; local extinction events.
5	Significant	• >70% change in relative abundance of trophic levels (based on biomass); >70% reduction of population abundances for top predator species; >30% reduction of population abundances for primary producer species. • If the alien species was removed, recovery is not expected; loss of trophic levels; potential trophic cascades resulting in significant changes to ecosystem structure, alteration of biodiversity patterns and changes to ecosystem function; significant local extinctions.

Table A5. Consequence matrix: Economic – Tourism

Level	Descriptor	Tourism Impacts
1	Insignificant	• Reduction in national income from tourism shows no discernible change. • No discernable change in strength of tourism activities. • If the alien species was removed, recovery is expected in days.
2	Minor	• Reduction in national income from tourism is <1%. • Reduction of strength in individual tourism activities is <1%. • Tourism is reduced to 99% of its original area (spatial context) within *[insert country/region/port name]*. • If the alien species was removed, recovery is expected in days to months, no loss of any tourism industry.
3	Moderate	• Reduction in national income from tourism is 1-5%. • Reduction of strength in individual tourism activities is 1-5%; • Tourism is reduced to less than 95% of its original area (spatial context) within *[insert country/region/port name]*; • If the alien species was removed, recovery is expected in years with the loss of at least one tourism activities.
4	Major	• Reduction in national income from tourism is 5-10% • Reduction of strength in individual tourism activities is 5-10%; • Tourism is reduced to less than 90% of its original area (spatial context) within *[insert country/region/port name]*; • If the alien species was removed, recovery is expected in decades with the loss of at least one tourism activities.
5	Significant	• Reduction in national income from tourism is >10% • Reduction of strength in individual tourism activities is >10%; • Tourism is reduced to less than 90% of its original area (spatial context) within the *[insert country/region/port name]*; • If the alien species was removed, recovery is not expected with the loss of multiple tourism activities.

Table A6. Consequence matrix: Economic – Fishing

Level	Descriptor	Fishing Impacts
1	Insignificant	• Reduction in national income from fishing shows no discernible change • Reduction in commercial species abundance shows no discernible change • No discernable change in quality of product • No discernable change in strength of fishing sectors • No discernable change in costs of harvesting product (incl. costs of handling, damage to gear or research to mitigate impact) • If the alien species was removed, recovery is expected in days
2	Minor	• Reduction in national income from fishing is <1% • Reduction in commercial species abundance is <1% compared to loss from other human mediated activities • Fishing is reduced to less than 99% of its original area (spatial context) within *[insert country/region/port name]* • Reduction to quality of product <1% • Increased costs of harvesting product (incl. costs of handling, damage to gear or research to mitigate impact) <1% • If the alien species was removed, recovery is expected in days to months, no loss of any fishing region
3	Moderate	• Reduction in national income from fishing is 1-5% • Reduction in commercial species abundance is 1-5% compared to loss from other human mediated activities • Fishing is reduced to less than 85% of its original area (spatial context) within *[insert country/region/port name]* • Reduction to quality of product 1-5% • Increased costs of harvesting product (incl. costs of handling, damage to gear or research to mitigate impact) 1-5% • If the alien species was removed, recovery is expected in less than a year and loss of at least one fishing region
4	Major	• Reduction in national income from fishing is 5-10% • Reduction in commercial species abundance is 5-10% compared to loss from other human mediated activities • Fishing is reduced to less than 90% of its original area (spatial context) within *[insert country/region/port name]* • Reduction to quality of product 5-10% • Increased costs of harvesting product (incl. costs of handling, damage to gear or research to mitigate impact) 5-10% • If the alien species was removed, recovery is expected in less than a decade and loss of at least two fishing regions
5	Significant	• Reduction in national income from fishing is >10% • Reduction in commercial species abundance is >10% compared to loss from other human mediated activities • Fishing is reduced to less than 90% of its original area (spatial context) within *[insert country/region/port name]* • Reduction to quality of product >10% • Increased costs of harvesting product (incl. costs of handling, damage to gear or research to mitigate impact) >10% • If the alien species was removed, recovery is not expected and loss of a number of fishing regions

Table A7. Consequence matrix: Economic – Aquaculture

Level	Descriptor	Aquaculture Impacts
1	Insignificant	• Reduction is national income from aquaculture shows no discernible change • No discernable change in quality of product. • No discernable change in strength of aquaculture sectors • No discernable change in costs of harvesting product (incl. handling costs, cost of damage to gear or research costs to mitigate impacts) • No discernable change in ability to sustain and expand aquaculture activities (incl. access to spat and/or opportunities expand an develop new and existing farms) • If the alien species was removed, recovery is expected in days.
2	Minor	• Reduction is national income from aquaculture is <1% • Aquaculture is reduced to less than 99% of its original area (spatial context) within *[insert country/region/port name]* • Reduction in quality of product <1% • Increase in costs of harvesting product (incl. handling costs, cost of damage to gear or research costs to mitigate impact) <1% • Reduction in ability to sustain and expand aquaculture activities (incl. access to past and/or opportunities expand an develop new and existing farms) <1% • If the alien species was removed, recovery is expected in days to months, no loss of any aquaculture region
3	Moderate	• Reduction is national income from aquaculture is 1-5% • Aquaculture is reduced to less than 95% of its original area (spatial context) within *[insert country/region/port name]* • Reduction in quality of product 1-5% • Increase in costs of harvesting product (incl. handling costs, cost of damage to gear or research costs to mitigate impact) 1-5% • Reduction in ability to sustain and expand aquaculture activities (incl. access to past and/or opportunities expand an develop new and existing farms) 1-5% • If the alien species was removed, recovery is expected in less than 1 year and loss of at least one aquaculture region
4	Major	• Reduction is national income from aquaculture is 5-10% • Aquaculture is reduced to less than 90% of its original area (spatial context) within *[insert country/region/port name]* • Reduction in quality of product 5-10% • Increase in costs of harvesting product (incl. handling costs, cost of damage to gear or research costs to mitigate impact) 5-10% • Reduction in ability to sustain and expand aquaculture activities (incl. access to past and/or opportunities expand an develop new and existing farms) 5-10% • If the alien species was removed, recovery is expected in less than a decade and loss of less than two aquaculture regions
5	Significant	• Reduction is national income from aquaculture is >10% • Aquaculture is reduced to less than 90% of its original area (spatial context) within *[insert country/region/port name]* • Reduction in quality of product >10% • Increase in costs of harvesting product (incl. handling costs, cost of damage to gear or research costs to mitigate impact) >10% • Reduction in ability to sustain and expand aquaculture activities (incl. access to past and/or opportunities expand an develop new and existing farms) >10% • If the alien species was removed, recovery is not expected and loss of a number of aquaculture regions

Table A8. Consequence matrix: Economic - Vessel / Moorings

Level	Descriptor	Vessel / Moorings Impacts
1	Insignificant	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <1% of annual cleaning costs • Increased costs associated with requirements to clean mooring sites are <1% of annual cleaning costs • Increased costs associated with increased maintenance on vessels and moorings as a result of fouling are <1% of annual cleaning costs • Lost business opportunities as a result of cleaning requirements / movement restrictions (incl. inability to access domestic / overseas ports) are <1% annual business turnover
2	Minor	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <10% of annual cleaning costs • Increased costs associated with requirements to clean mooring sites are <10% of annual cleaning costs • Increased costs associated with increased maintenance on vessels and moorings as a result of fouling are <10% of annual cleaning costs • Lost business opportunities as a result of cleaning requirements / movement restrictions (incl. inability to access domestic / overseas ports) are <10% annual business turnover
3	Moderate	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <20% of annual cleaning costs • Increased costs associated with requirements to clean mooring sites are <20% of annual cleaning costs • Increased costs associated with increased maintenance on vessels and moorings as a result of fouling are <20% of annual cleaning costs • Lost business opportunities as a result of cleaning requirements / movement restrictions (incl. inability to access domestic / overseas ports) are <20% annual business turnover
4	Major	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <40% of annual cleaning costs • Increased costs associated with requirements to clean mooring sites are <40% of annual cleaning costs • Increased costs associated with increased maintenance on vessels and moorings as a result of fouling are <40% of annual cleaning costs • Lost business opportunities as a result of cleaning requirements / movement restrictions (incl. inability to access domestic / overseas ports) are <40% annual business turnover
5	Significant	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are >40% of annual cleaning costs • Increased costs associated with requirements to clean mooring sites are >40% of annual cleaning costs • Increased costs associated with increased maintenance on vessels and moorings as a result of fouling are >40% of annual cleaning costs • Lost business opportunities as a result of cleaning requirements / movement restrictions (incl. inability to access domestic / overseas ports) are >40% annual business turnover

Table A9. Consequence matrix: Social - Aesthetics / Diving

Level	Descriptor	Aesthetics / Diving Impacts
1	Insignificant	• Reduction in the quality of the diving experience, in terms of access, visibility and safety, is <1% • Reduction in the quality of the diving experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <1% • If the alien species was removed, recovery is expected in days.
2	Minor	• Reduction in the quality of the diving experience, in terms of access, visibility and safety, is <10% • Reduction in the quality of the diving experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <10% • Diving is reduced to less than 90% of its original area (spatial context) • If the alien species was removed, recovery is expected in weeks to months.
3	Moderate	• Reduction in the quality of the diving experience, in terms of access, visibility and safety, is <20% • Reduction in the quality of the diving experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <20% • Diving is reduced to less than 80% of its original area (spatial context) • If the alien species was removed, recovery is expected in less than a year.
4	Major	• Reduction in the quality of the diving experience, in terms of access, visibility and safety, is <40% • Reduction in the quality of the diving experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <40% • Diving is reduced to less than 70% of its original area (spatial context) • If the alien species was removed, recovery is expected in less than a decade.
5	Significant	• Reduction in the quality of the diving experience, in terms of access, visibility and safety, is >40% • Reduction in the quality of the diving experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is >40% • Diving is reduced to less than 60% of its original area (spatial context) • If the alien species was removed, recovery is not expected.

Table A10. Consequence matrix: Social - Vessel / Access

Level	Descriptor	Vessel / Access Impacts
1	Insignificant	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <1% of annual cleaning costs • Reduction in recreational enjoyment as a result of movement restrictions (incl. inability to access domestic / overseas ports) is <1% • Increased costs associated with increased maintenance on vessels / vectors as a result of fouling are <1% of annual cleaning costs
2	Minor	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <10% of annual cleaning costs • Reduction in recreational enjoyment as a result of movement restrictions (incl. inability to access domestic / overseas ports) is <10% • Increased costs associated with increased maintenance on vessels / vectors as a result of fouling are <10% of annual cleaning costs
3	Moderate	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <20% of annual cleaning costs • Reduction in recreational enjoyment as a result of movement restrictions (incl. inability to access domestic / overseas ports) is <20% • Increased costs associated with increased maintenance on vessels / vectors as a result of fouling are <20% of annual cleaning costs
4	Major	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are <40% of annual cleaning costs • Reduction in recreational enjoyment as a result of movement restrictions (incl. inability to access domestic / overseas ports) is <40% • Increased costs associated with increased maintenance on vessels / vectors as a result of fouling are <40% of annual cleaning costs
5	Significant	• Increased costs associated with requirements to clean vessels / vectors before moving from one location to another are >40% of annual cleaning costs • Reduction in recreational enjoyment as a result of movement restrictions (incl. inability to access domestic / overseas ports) is >40% • Increased costs associated with increased maintenance on vessels / vectors as a result of fouling are minimal (>40% of annual cleaning costs)

Table A11. Consequence matrix: Social - Recreational Harvest

Level	Descriptor	Recreational Harvest Impacts
1	Insignificant	• Reduction in the quality of the recreational harvest experience, in terms of access, visibility and safety, shows no discernible change • Reduction in the quality of the recreational harvest experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, shows no discernible change • If the alien species was removed, recovery is expected in days.
2	Minor	• Reduction in the quality of the recreational harvest experience, in terms of access, visibility and safety, is <10% • Reduction in the quality of the recreational harvest experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <10% • Recreational harvest is reduced to less than 90% of its original area (spatial context) • If the alien species was removed, recovery is expected in weeks to months.
3	Moderate	• Reduction in the quality of the recreational harvest experience, in terms of access, visibility and safety, is <20% • Reduction in the quality of the recreational harvest experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <20% • Recreational harvest is reduced to less than 80% of its original area (spatial context) • If the alien species was removed, recovery is expected in less than a year.
4	Major	• Reduction in the quality of the recreational harvest experience, in terms of access, visibility and safety, is <40% • Reduction in the quality of the recreational harvest experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is <40% • Recreational harvest is reduced to less than 70% of its original area (spatial context) • If the alien species was removed, recovery is expected in less than a decade.
5	Significant	• Reduction in the quality of the recreational harvest experience, in terms of access, visibility and safety, is >40% resulting the area no longer being utilised • Reduction in the quality of the recreational harvest experience, in terms of naturalness of the surrounding habitat and the diversity of organisms, is >40% • Recreational harvest is reduced to less than 60% of its original area (spatial context) • If the alien species was removed, recovery is not expected.

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Appendix B: Organism Impact Assessment (OIA) – Valuation (modified from Campbell 2005c; Campbell and Hewitt *in prep*)

What is valuation?

When undertaking an organism impact assessment valuation must occur. In this instance we define value as the monetary worth/ marketable price, or scale of usefulness/importance we place on an ecosystem, its services and benefits. We assess value at the level of the environment, the economy, socially and culturally (the four core values). Each core value consists of a suite of subcomponents. For example, in a freshwater/estuarine port, the environmental core value may consist of rare and endangered species, biodiversity, and water chemistry, whilst the economic value may include the infrastructure, tourism occurring in the port and commercial fishing. The numerous subcomponents to each core value will differ from region to region (spatial), through time (temporal) and between how individuals perceive an area. Because of these shifting spatial, temporal and perceived values, and coupled with the diversity of ecosystems, services and benefits, valuation is difficult to assess. To overcome this, economic theorists have developed a number of methods that enable differing ecosystems to be valued. Although monetary units are often used as they are easily understood and facilitate comparison this does not have to be the unit of measure. For example a value continuum can be implemented that assesses value based on a rate or scale of usefulness or importance (Figure B1).

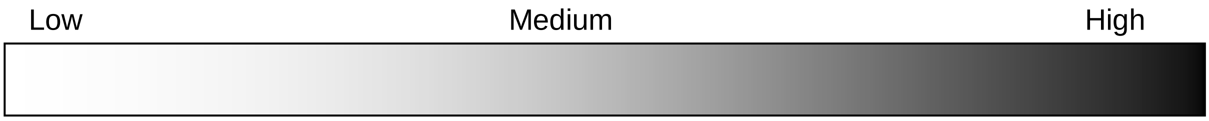

Figure B1. The value continuum concept. Value(s) increases or decreases along the continuum, with terms such as low, medium and high being used to classify where on the continuum the real and/or perceived value lies.

Valuation of the core values can be positive/realised (what is, what was, what will be) or normative (what ought to be). Positive valuation is based on data and facts, with normative valuation aiming to determine the optimal level of impact. Normative approaches involve value judgment and are hence, are open to variation and debate. Typically, environmental, social and cultural core values are assessed from a normative perspective because they contain subcomponents that are difficult to place a dollar value against.

To date, ecosystem value (including its goods and services) has typically relied on economic tools to assess how they are used (see Total Economic Value [TEV]; Figure B2). These tools attempt to simplify how we view the world and its assets by categorising them into use and non-use values. Use values are further divided into direct use, indirect use, and option (Figure B2). Direct use value refers to ecosystem goods and services that are used directly by human beings. These values are most often enjoyed by people visiting or residing in the ecosystem itself. Indirect use value is derived from ecosystem services that provide benefits outside the ecosystem itself (e.g., carbon sequestering by mangroves). Option values are derived from preserving the option to use in the future ecosystem goods and services that may not be used at present, either by oneself (option) or by others/heirs (bequest). Non-use values are existence values and typically refer to the enjoyment people may experience simply by knowing that a resource exists even if they never expect to use that resource directly themselves.

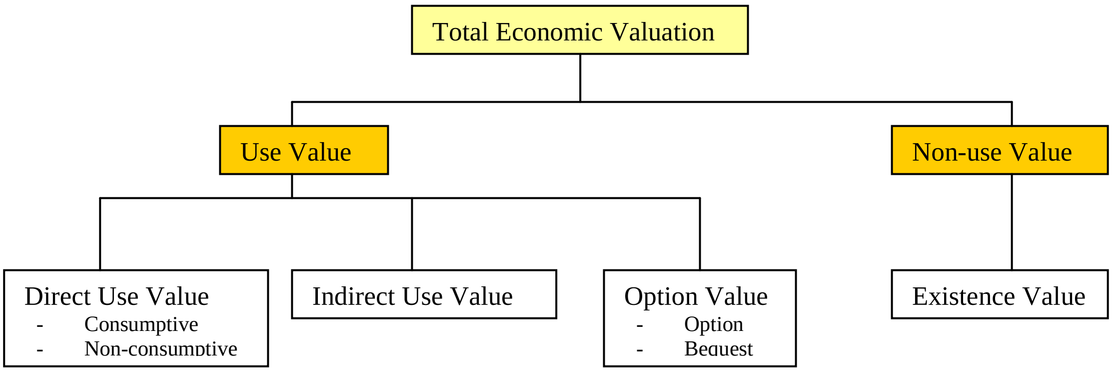

Figure B2. Total Economic Value (TEV) conceptual framework (from Pagioli et al. 2004).

Assessment of value uses various methods such as revealed preference methods (travel costs, hedonic pricing, replacement cost, production function etc) and stated preference methods (contingent valuation, choice modelling). The use of benefits transfer also exists as a valuation technique. Pagioli et al. (2004) provide an excellent summary of valuation techniques, their approach, application, data requirements and limitations.

Within New Zealand, Organism Impact Assessments have typically used contingent- and where possible, market valuation techniques. These methods are commonly used in terrestrial and freshwater research evaluations (e.g., Braden and Kolstad 1991; Tietenberg 1992; Brown and Moran 1993; Barbier 1994; Barbier and Aylward 1996; Bishop 1998; Reid 2001; Emerton and Bos 2004) and to a lesser extent in marine systems (Norse 1993). Contingent Valuation Methods (CVM) work by asking focus group participants their beliefs as to the value of a specified service, or their willingness to pay to preserve this specified service. It is applicable to all ecosystem services and benefits, but is typically used for non-use values (see Gilpin 2000; Chee 2004; Pagioli et al. 2004). There are shortcomings to this method: strategic behaviour, protest answers, response bias and respondents ignoring incomes constraints (Daimond and Hausman 1994; Chee 2004). It's important to ensure that respondents don't express a general preference for environmental spending in their answers (known as embedding effect; Kahneman and Knetsch 1992). Typically these problems are overcome by ensuring that:

i. Personal interviews are held, not telephone calls or mail-outs;
ii. Surveys are designed in a yes-no referendum style format or directed in such a way that open-ended questions are avoided;
iii. Participants are given detailed information on the resource in question and on protection measures they are 'voting' on. This information should include threats to the resource, scientific evaluation or its ecological importance and possible outcomes of protection measures;
iv. Income effects are carefully explained to enure that participants understood that they were to express their willingness to pay to protect the resource in question, not the environment generally; and
v. Subsidiary questions are asked to ensure that the participants understood the question posed.

There are many potential sources of bias in responses with guidelines existing to ensure reliable applicable of CVM. Thus, the assessor (workshop chair/convener) has a high burden of proof to satisfy before results can be seen as meaningful.

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Appendix C: Organism Impact Assessment – Deriving Value and Consequence (modified from Campbell 2005c)

Table C1. Summary of three regional focus groups perceptions of value of core values prior to an alien species is introduced. Average value is indicated in parentheses. Ranges represent the variability (uncertainty) in perceptions. Priceless denotes a value equivalent to $1billion. Cultural values were assessed on a scale of importance. hh denotes the dollar value a household is willing to pay to prevent/mitigate an alien species problem.

	Perceived Value Range (average ± SD)		
Core Value	**Region 1**	**Region 2**	**Region 3**
Environment	$10/hh* - $5,000/hh ($730/hh ± 1, 170)	$10 million – priceless ($195 million ± 350 million)	$32 million – priceless ($120 million ± 380 million)
Economic	$100,000 - $370 million ($70 million ± 95 million)	$0 – priceless ($225 million ±320 million)	$10 million – priceless ($270 million ± 280 million)
Social	$1/hh – priceless ($100 million/hh ± 310 million)	$2 million – priceless ($120 million ± 290 million)	$1 million – priceless ($915 million ± 195 million)
Cultural	Very low to very high (65.6)	Moderate to very high (75)	Moderate – very high (93)

Table C2. Summary of three regional focus groups perceptions of change in value following on from an alien species incursion. Average percent perceived change is indicated in parentheses, which are averages of the core value subcomponent groupings. Cultural values were assessed on a scale of importance.

	Range of Perceived Change in Value (%)		
Core Value	**Region 1**	**Region 2**	**Region 3**
Environment	90-100 (95%)	0-100 (45%)	10-95 (45%)
Economic	0-100 (33%)	10-100 (78%)	1-100 (49%)
Social	0-60 (24%)	0-40 (16%)	20-100 (72%)
Cultural	Very small to moderate (22%)	Small to large (48%)	Very small to very large (33%)

Table C3. Summary of three regional focus groups perceptions of impact (consequence) following on from an alien species incursion. Consequence is derived from the consequence matrices (Appendix A), where the percent change is assessed against the percent descriptor in the consequence matrices.

	Perceived Consequence		
Core Value	**Region 1**	**Region 2**	**Region 3**
Environment	Significant	Major	Major
Economic	Significant	Significant	Significant
Social	Major	Moderate	Significant
Cultural	Major	Significant	Major

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