Marine Environmental Risk Assessment and Management:

Putting into practice an ecosystem-based management approach

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"One of the great mistakes is to judge policies and programs by their intentions rather than their results."

Milton Friedman

Preface

Background of the Author

For more than 35 years, I worked in fisheries stock assessment, seafood safety and more recently in freshwater and marine ecosystem management. At Fisheries and Oceans Canada (DFO) and the Canadian Food Inspection Agency (CFIA), my work reflects a long standing interest for effective bridges between science and management including regulatory processes. In the 1990's, the Sanitary and Phytosanitary Agreement of the World Trade Organization introduced the need for risk assessment in the selection of technical measures to protect human, animal and plant health as a means to reduce the use of technical barriers to trade. This triggered the development of food safety programs based on hazards analysis and critical control point (HACCP) to reduce the likelihood of hazards in food products destined for human consumption. During that time, my work on HACCP-based seafood programs and shellfish biotoxins surveillance gave me the opportunity to acquire a more in-depth understanding of the role of risk assessment to bridge the scientific knowledge regarding food hazards with the development of technical measures to reduce these risks in seafood. However, it was during my assignment at the Food and Agriculture Organization of the United Nations (FAO), that I understood the normative role of scientific knowledge in the development of seafood safety policies and standards. Given that HACCP-based programs are designed to manage the potential introduction of food hazards from harvest to the consumer, my attention shifted to the food hazards that can arise from the quality of the marine environment where fish and shellfish are being harvested. Based on FAO policy, seafood safety is one of the many factors that are considered within the context of food security where HACCP approaches cannot prevent the inherent environmental hazards such as heavy metals. Returning to DFO in 2005, I was given the opportunity to manage and direct ecosystem-based management programs in the protection of fish and fish habitat, integrated oceans management and species at risk recovery planning. Here, I explored the use of risk management approaches to bridge ecosystem science with the development of environmental protection policies and regulatory frameworks as well as marine conservation strategies. Here, I saw the need for a normative approach to scientific advice given the need to understand the effectiveness of the regulatory and non-regulatory measures used to manage human activities in freshwater and marine environments. Up to this point in time, ecosystem science conducted considerable research in the understanding of ecosystem structures, functions and processes within the context of the ecosystem-based approach to management. At the time, there was considerable science regarding the impacts and effects of the pressures generated by human activities and the use of marine protected areas for conservation strategies. Given my background in HACCP programs, I realized that there was and still is much less science in the effectiveness of the regulatory and non-regulatory frameworks used in the management of those activities. Having examined environmental and ecosystem risk assessment approaches to identify ecosystem vulnerabilities, I then pursued the implementation of risk management standards in ecosystem-based management approaches. As part of a risk management standards such as ISO 31000, a risk assessment is conducted to identify the measures that are needed to reduce the uncertainties of achieving policy objectives in contrast to a risk assessment of the likelihood and magnitude of the impacts. Having chaired many environmental assessment and management processes, I was able to gradually integrate risk management processes to improve the standards, the codes of practices or the guidelines that would be implemented to achieve policy objectives. Given the broader range of environmental, cultural, social and economic objectives in marine planning, I also collaborated with anthropologists and social scientists to develop criteria and approaches to improve the cultural knowledge needed to inform these processes.

Over the years, I consider that I have acquired an understanding of a broad range of disciplines given my work in marine science, risk management, policymaking, and regulatory frameworks. Having published several papers and chaired many workshops regarding ecosystem-based management and risk management, this thesis constitutes the submission of my research portfolio for a PhD by published work.

Purpose and Structure of the thesis

This thesis provides the evidence required for examination for a PhD by published work at the University of Hull, in accordance with the University Programme Regulations Chapter XXIII (v1 02, November 2014). Following University guidelines, this thesis is structured as follows: Abstract; Table of Contents; List of Figures; List of Tables; Chapter 1: Introduction; Chapter 2: Concepts and premises in this thesis; Chapter 3: Practical aspects of marine planning and management; Chapter 4: Reducing the uncertainties of achieving policy objectives; Chapter 5: Discussion and Chapter 6: Conclusions. Annex 1: is the list of published work for this thesis and the papers used as supporting literature including testimonials.

Acknowledgements

I especially would like to thank Professor Mike Elliott from the Institute of Estuarine & Coastal Studies for the guidance and advice in the preparation of this thesis. After having invited him to an ICES workshop in 2012 in Canada, Mike has become a great friend and colleague. We have since collaborated on several projects, papers and meetings that have provided me with valuable insights and knowledge in the marine sciences and management. I would also like to acknowledge Dr Jake Rice, Emeritus Scientist at Fisheries and Oceans Canada who is also a great friend and colleague. Our debates and collaborations on a variety of science advisory and policy development initiatives have shaped my views and perspectives expressed in this thesis. I would also like to acknowledge Dr Valerie Cummins (University College Cork, Ireland) and Dr Bryony Caswell (University of Hull, UK) as External and Internal Examiners respectively, for their extremely valuable comments and discussion on an earlier version of this thesis. I would like to thank my colleagues for their support as I pursued my research in trying to bring the sciences and management closer together for almost 40 years now. Finally, I truly would like to thank my husband Kevin Charchuk for his support and the picture he provided for the cover page.

Abstract

In addition to the complexities of marine ecosystems and the current state thereof, marine management is even more complex given the range of activities and legislation to manage them. Marine planning processes are considered as the means for an integrated management approach to address ecosystem concerns while promoting sustainable growth, development, and use. Although marine plans are mostly considered as an ecosystem-based approach to management and conservation, they seldom provide clarity as to how their objectives are to be achieved. In policymaking, administrations develop and implement standards, codes of practice or guidelines to "*carry into effect*" the policy objectives through regulatory and non-regulatory frameworks. In fact, environmental protection regulatory frameworks used to manage human activities and their pressures in the marine environment are such frameworks. The effectiveness of marine protected areas is shown to be dependent on the pressures generated outside the protected area even though activities within such areas are prohibited. In this thesis, I discuss the need to integrate environmental protection regulatory frameworks and conservation measures as a comprehensive environmental protection and conservation strategy for managing human activities at large while protecting vulnerable ecosystem structures, functions and processes. Given the need to understand the effectiveness these regulatory frameworks to achieve broader ecosystem and conservation objectives, I also propose the use of risk management standards and tools. These standards were developed to identify the management measures needed to achieve policy objectives in contrast to an assessment of impacts risks. In an ecosystem-based management context, these standards and tools assign a prevention role to environmental protection regulatory frameworks and a mitigation and recovery role to conservation measures.

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1 Introduction

Currently, the marine environment is considered to be under tremendous pressures from human activities (Halpern et al., 2015). Marine protected areas are also falling short of their objectives as a result of the pressures generated by human activities occurring outside these protected areas (Mach et al., 2017). Even though ecosystem-based management has been enshrined in multiple pieces of environmental legislation and United Nations (UN) conventions, the so-called operational implementation of the ecosystem-based management approach remains elusive after decades of academic and policy work in this area (Link and Browman, 2017). Although years of integrated oceans management and marine spatial planning initiatives have been primarily focused on setting objectives to guide ecosystem-based management decisions, few have translated these into enhanced regulatory frameworks used to manage marine sector activities (Hall et al., 2011; Jessen, 2011; Zaucha and Gee, 2019). Although there is no need to debate the significance of the changes occurring in marine environments, we may have reached a point where protection and conservation strategies cannot effectively protect the abiotic and biotic ecosystem components and, thus, require a much better integration of how human activities and their pressures are individually managed by their respective regulatory frameworks with conservation strategies (#02 Cormier et al., 2018; #04 Cormier et al., 2019; Robb et al., 2011)[1].

Aside from natural variations and the effects of climate change, this research is based on the premise that the root causes of marine environmental effects and their impacts are the net result of current and past regulatory frameworks used to manage marine activities and their collective pressures (#01 Cormier et al., 2017). Given that thousands of standards and regulations are used by regulators to manage a broad range of pressures generated by marine activities (Boyes and Elliott, 2014), the effectiveness of those standards and regulations needs to be improved if the collective pressures are undermining marine environmental policy objectives (#02 Cormier et al., 2018; Spalding and Fox, 2007). Marine conservation is primarily an exercise of spatial protection measures for unique habitat features and vulnerable species. Such strategies are not as effective at protecting these habitats and species from other land-

[1] The use of #n refers to a published paper included in this thesis.

based and marine pressures such as contaminants, noise, litter, nutrients, and non-indigenous species. Conservation efforts alone will ultimately be in vain if we can't align the effectiveness of environmental protection regulatory frameworks to reduce the collective pressures with these efforts (#04 Cormier et al., 2019).

However, objectives found in policies, integrated oceans management plans and marine spatial plans are not always conducive or specific enough to develop management measures to be implemented by regulatory frameworks designed to address very specific industry sectors and marine activities (#3 Cormier and Elliott, 2017). In addition, the expectations of most marine spatial planning initiatives are often greater than the scope of the planning processes given the broad range of environmental, social and economic concerns being expressed by stakeholders (#06 Cormier and Kannen, 2019). The challenge lies in the abilities and capacities of administrations to manage the processes and expectations while respecting the scope of the process within their legislative mandates (#07 Cormier, 2019; #12 Cormier et al., 2015; #13 Cormier et al., 2016). Standardized risk management processes and tools are used to identify the management controls needed to achieve objectives within the scope of a policy in contrast to assessing the risks of potential impacts. Risk management processes are considered to be a valuable ecosystem-based management approach to integrate environmental protection regulatory frameworks and conservation strategies because of the need to analyse the effectiveness of the measures to achieve environmental protection and conservation objectives (#04 Cormier et al., 2019; #05 Cormier and Lonsdale, 2019; #08 Cormier et al., 2018; #11 Cormier et al., 2013).

In this thesis, I examine the challenges faced by managers, stakeholders and scientists involved in marine planning and regulatory implementation processes in the integration of marine environmental protection and conservation strategies. Thus, I introduce the need to understand the goals and objectives of legislation and policies used to implement these strategies with a particular attention to the expected outcomes of their regulatory frameworks before starting any kind of assessment. I then put forth the need to assess the effectiveness of the protection and conservation measures used in these regulatory frameworks as an integral part of any marine environmental or ecosystem assessments. I introduce the value of international risk management standards where risk is defined as the effect of uncertainty on achieving policy objectives in contrast to risk equals impacts and probability (ISO, 2018). In such a standard, a decision to manage a risk is not only based on the severity of an impact. It is based on the effectiveness of the management measures in reducing the likelihood of such impact thus reducing the uncertainties of achieving a policy objective. Finally, I discuss the value of using risk management approaches to integrate the protection and conservation strategies based on the effectiveness of the measures implemented in both to achieve environmental objectives.

The papers in this thesis are the result of my contributions to a variety of national and international marine policy and regulatory initiatives within the context of the Canadian marine legislation, the EU Marine Strategy Framework Directive (MSFD) (EC, 2017a, 2008), the Maritime Spatial Planning Directive (MSPD) (EC, 2014) and the United Nations Convention on the Law of the Sea (UNCLOS) (UN, 1996) including regulatory approaches to the implementation of the United Nations Sustainable Development Goals (UNECE, 2017, 2018). Risk management is discussed from an ecosystem-based policy perspective given that cultural, social and economic aspects would exceed the scope of this thesis.

2 Concepts and principles

The treatise of the subject matter in this thesis draws upon the concepts and principles of policymaking, legal frameworks, schools of management, public administration, risk management and the ecosystem-based principles. The following is a description of the concepts and principles that were derived from these disciplines in the treatise of the subject matter.

- Anderson (2011) defines policy as "*a relatively stable, purposive course of action or inaction followed by an actor or set of actors in dealing with a problem or matter of concern*" (Anderson, 2011). However, he also stipulates that a policy is what is done after a decision among alternatives choices of action. In a legislative policymaking context, administrations develop and implement standards, codes of practices and guidelines as part of a regulatory or non-regulatory framework to "*carry into effect*" the policy objectives within the context and scope of the legislation. The policy is not implemented *per se* as is often expressed in marine planning and management. Policy objectives are achieved through control measures that produce the intended result or expected outcomes that are in line with the objectives to be achieved (Anthony and Dearden, 1980). Control measures are considered effective when they produce the expected outcomes. Marine spatial plan or an integrated oceans management plan is not likely going to '*carry into effect*' their objectives without the implementation of control measures to manage human activities and their pressures by those that have the legislative authority to do so in contrast to those that have the authority to facilitate a marine planning process (#01 Cormier et al., 2017).

- The role of environmental protection and conservation strategies are used interchangeably to mean the same thing. Environmental protection regulatory frameworks have a long history of managing human activities and their pressures on marine ecosystems going back to environmental pollution in the 1960's. These frameworks regulate the amounts and types of deleterious substances and habitat alterations as well as where and when the activities that generate these should occur. Given their legislative context and scope, these regulatory frameworks are intended to provide protection in many ecological contexts without necessarily considering the broader ecosystem context (#04 Cormier et al., 2019). This is in contrast to conservation regulatory frameworks that regulate all relevant activities in relation to unique ecosystem structures or functions such as a marine protected area regulation. However, the effectiveness of conservation regulatory frameworks or measures can be undermined in cases where the effectiveness of the environmental protection regulatory frameworks does not produce the expected outcomes needed to address the conservation objectives (#02 Cormier et al., 2018; #05 Cormier and Lonsdale, 2019).
- Hazards, threats and risks are a matter of policy or, rather, a matter of anthropomorphic contexts and values. We can consider hazards to our well-being or for the preservation of nature and species. In nature, there are no intrinsic hazards, threats and risks. Nature is simply a complex mix of abiotic

and biotic processes where species adapt, evolve or disappear because of changing conditions. Nature does not setup committees of species to threaten individual organisms or us. The consequences of natural variations and changes is mostly a matter of chance and the inherent processes of the ecosystem. Furthermore, people do not use resources or pursue opportunities with the explicit objective of threatening marine ecosystems. From a policy perspective, impacts and harm are a policy expression of the inadvertent consequences of these activities. Given the wide range of natural and human generated hazards (Elliott et al., 2014), risks is inherently linked to the context of the policy objectives where the scope also sets the boundaries of the hazards that could undermine these objectives (#03 Cormier and Elliott, 2017). Therefore, marine planning needs to identify the relevant policies and the scope of the hazards that need to be addressed to achieve environmental, cultural, social and economic objectives to protect the marine environment and our well-being (#09 Elliott et al., 2017). In short, a marine process should ultimately identify the management measures needed to "carry into effect" the objectives of the plan.

- An assessment of risk outside the context of a policy is for the most part a reflection of the concerns expressed by the person doing the assessment (#07 Cormier, 2019). Although environmental and ecological risk assessments are valuable approaches to identify ecosystem vulnerabilities for consideration in management decisions, they seldom include an assessment of the management measures that could reduce these risks (#10 Astles and Cormier, 2018). The aim of risk management standards such as ISO 31000 is to assess the risks of not achieving a policy objective based on the effectiveness of existing management controls and to evaluate options to improve the controls or add new ones (#02 Cormier et al., 2018; #04 Cormier et al., 2019). Given the broad range of objectives, risks and regulatory frameworks involved in marine management, marine planning and the ultimate implementation of the plan is technically a risk management process (#06 Cormier and Kannen, 2019).

3 Practical aspects of marine planning and management

Working from the premise that the effects caused by the pressures generated by human activities are the net result of the effectiveness (or otherwise) of their environmental protection regulatory frameworks, there is a need to understand the context and the scope of these regulatory frameworks to understand how their expected outcomes align with ecosystem-based objectives and outcomes in marine planning. It is also important to understand the legislation and the policies that are providing the mandate for the planning process given that the scope of the process could either be for sector development or conservation. Rarely does legislation address both mandates at once and, thus, a planning process for sector development would need to include environmental protection strategies for the sectors being planned while conservation planning processes concerned with vulnerable ecosystem structures, functions and processes would need to consider the pressures generated by the sector development strategies. This is the key reason why a planning process has to start with an understanding of the legislative mandate given to the manager or planner because it defines the goals, objectives and expectations of the planning initiative (#05 Cormier and Lonsdale, 2019; #07 Cormier, 2019; #08 Cormier et al., 2018; #13 Cormier et al., 2016; #14 Cormier, 2019; Sarda et al., 2014). In Canada as well as with other legislation, an analysis of the legislation and mandate conducted in consultation with regulators, stakeholders and scientists helps everyone understand why and what the planning initiatives is trying to achieve and how the resulting plan would be implemented in a transparent manner.

In addition to a lack of understanding of the context and scope of a planning initiative, ambiguous goals, objectives and outcomes can also significantly hamper a planning process, in particular, when goals, objectives, and outcomes are expressed interchangeably or out of context by those involved. There is sometimes a need to spend considerable time with everyone involved to identify and formulate the goals, the objectives and the expected outcomes of the management measures when these are not clearly provided by legislation and policy (#03 Cormier and Elliott, 2017; #05 Cormier and Lonsdale, 2019). This also avoids misunderstandings that can lead to a loss of credibility and trust in the process (#12 Cormier et al., 2015). It ultimately helps in providing relevant feedback and advice. In either planning context, a review of the environmental protection and conservation strategies and regulatory frameworks helps understand how or who would be responsible to implement the various management measures that would figure in the marine plan as well as identify opportunities for improvements (#02 Cormier et al., 2018; #08 Cormier et al., 2018; #14 Cormier, 2019). This avoids the pitfalls of assuming that there is nothing being managed and that new measures are required or that everything should be managed through conservation strategies (e.g. marine protected areas) without considering improvements to the environmental protection management strategies (e.g. contaminant and pollution regulations).

Finally, this Chapter introduces the need for formal scientific advisory processes to provide independent and impartial advice to those involved in the planning process. Such a process is a peer-review of the science used to formulate the policy advice and not a peer-review of the science being published in a paper. In addition to providing advice for specific management questions and concerns, such processes can also be used for more normative scientific advice such as conceptual frameworks, criteria and methodologies that can be used in multiple advisory processes by scientists as well as for helping planners formulate their questions in consultation with stakeholders (DFO, 2004, 2006, 2009a, 2012a).

3.1 Understanding regulatory frameworks to manage activities and pressures

As opposed to ecosystem-based science that generates knowledge of ecosystem structures, functions and processes, ecosystem-based management should be an integrated management approach of human activities to maintain ecosystem health, productivity and resilience to deliver ecosystem services (Foley et al., 2010; McLeod et al., 2005). In planning, marine ecosystem-based science provides an understanding of the marine ecosystems and identifies the range of activities that are or may be causing impacts to these ecosystems (Halpern, 2009). From a management perspective, ecosystem-based management requires a process to identify the range of environmental protection and conservation measures that are needed to reduce these impacts (#01 Cormier et al., 2017; de la Mare, 2005; Gavaris, 2009).

In practice, marine activities and the pressures they generate are managed by a myriad of standards, codes of practice, and guidelines that are implemented through their respective environmental protection regulatory frameworks (Boyes and Elliott, 2014; McDorman and Chircop, 2012). In fact, this approach has been the hallmark of fisheries management and pollution legislation for decades (Bell et al., 2013; Garcia et al., 2014). Most of these frameworks are designed to manage localized impacts within the footprint of individual marine activities (#08 Cormier et al., 2018; #15 Creed et al., 2016; Coker et al., 2010; Kalafatis et al., 2015; Lodge and Verlaan, 2018). In ecosystem-based management, this is central to the criticism regarding piecemeal management approaches by species, by activity or by concern (McLeod et al., 2005). Although management strategies that are focused on ecosystem structures, functions and processes are favoured as a more holistic approach, such conservation strategies are not necessarily effective at reducing all possible pressures and still require effective environmental protection strategies that are tailored to the pressures generated by specific activities (#01 Cormier et al., 2017; Murawski, 2007).

With the arrival of ecosystem-based legislation such as the Canadian *Oceans Act* or the European Wild Bird and Habitat directives (Canada, 2019a; EC, 2010a, 2007), conservation strategies shifted management attention to reducing impacts to ecosystem structures, functions and processes through marine protected areas and environmental quality guidelines (De Santo and Jones, 2007; Fock, 2011; O'Boyle and Jamieson, 2006; Vandermeulen and Cobb, 2004). However, integrated coastal and oceans management also under the Canadian *Oceans Act* and, in particular, the European MSFD introduced the need to manage and reduce the collective pressures generated by human activities in addition to conservation strategies (Apitz et al., 2006; Piet et al., 2019; Ricketts and Harrison, 2007).

This inadvertently introduces some confusion regarding the roles of environmental protection and conservation strategies (#05 Cormier and Lonsdale, 2019; #08 Cormier et al., 2018). Environmental protection strategies regulate individual activities and their pressures that could have an impact on any local habitats and species while conservation strategies favour spatial prohibitions of marine activities to achieve broader ecosystem objectives (#04 Cormier et al., 2019). Given that the expected outcomes of these two strategies are not the same, it is clear that those involved in marine planning processes need to understand the subtle differences between sector-based environmental protection regulatory frameworks and marine conservation regulatory frameworks. Moreover, this would also require an understanding of the effectiveness of these regulatory frameworks as being fit for the purpose of achieving broader ecosystem and conservation objectives. Given that many environmental protection regulatory frameworks are used independently to manage marine activities (Boyes et al., 2016; Cavallo et al., 2018), integration has more to do with aligning the outcomes of these frameworks with the ecosystem and conservation outcomes established by conservation strategies to address the shortfalls of current integrated management practices (Heck et al., 2012; Jessen, 2011; Ricketts and Hildebrand, 2011; van Hoof, 2015; van Leeuwen et al., 2014). Given that spatial conservation strategies alone such as marine protected areas cannot address pressures outside a marine protected area (Agardy et al., 2011; Mach et al., 2017), improvements would be needed to the effectiveness of current environmental protection regulatory frameworks to complement marine conservation strategies (#01 Cormier et al., 2017; #04 Cormier et al., 2019; #14 Cormier, 2019; DFO, 2009b, 2009c).

An analysis of almost 1,400 cited instruments listed under the MSFD shows that there are nearly 500 EU level regulations that exist to manage a broad range of pressures (#08 Cormier et al., 2018). Mostly dealing with pollution and fisheries, the bulk of these regulations were developed prior to the 2000's with some going back to the 1960's. Similar examples are also found in Canadian environmental protection regulatory frameworks such as the *Canadian Environmental Protection Act* and the *Fisheries Act* (#14 Cormier, 2019). These regulatory frameworks regulate marine activities and their pressures on the marine environment in terms of the introduction of toxic and deleterious substances and habitat alterations.

Regulatory frameworks are also used for conservation strategies to manage human activities and their pressures on specific marine ecosystem structures and functions. Although referred to as protection, a marine protected area is implemented through conservation regulatory frameworks to implement a spatial prohibition for relevant human activities to conserve a unique or significant ecosystem component given the functions and species it supports. The nuance here is that environmental protection measures regulate the input, the spatial and temporal distribution of the pressures generated by land-based, coastal and marine human activities anywhere in the marine ecosystem while the conservation measures regulate the pressures within the spatial boundary of a given ecosystem component. Marine protected area regulations rarely regulate human activities outside the protected area as these are mostly delegated to the environmental protection regulatory frameworks (Boyes et al., 2003; Horta e Costa et al., 2016; Kelaher et al., 2015). In fact, marine conservation regulatory frameworks can only limit or prohibit marine activities within the area occupied by the vulnerable ecosystem components. Furthermore, the processes to establish marine protected areas are often carried out without fully considering the potential effects that could be generated by the collective pressures outside the area of concern (Agardy et al., 2011; Mach et al., 2017; Whitney et al., 2016). As the collective pressures increase from continued human development, environmental protection regulatory frameworks may become ineffective at managing their respective pressures and may ultimately undermine the ecosystem or conservation objectives of marine protected areas.

As an integration approach to conservation strategies, simply adding ecosystem or conservation objectives to an environmental protection regulatory frameworks used to manage pressures from human activities at large does not take into account the residual pressures of their measures (#02 Cormier et al., 2018). For example, measures used to control effluents released into the marine environment or sediments generated from dredging activities are not totally effective. They cannot eliminate all of the pressures generated by an activity. Instead of trying to solve everything with conservation measures such as marine protected areas, a planning process should identify the protection measures that are most effective at reducing specific pressures given the ecosystem concerns as a comprehensive ecosystem-based management strategy (#01 Cormier et al., 2017; #04 Cormier et al., 2019; #07 Cormier, 2019; #08 Cormier et al., 2018; #13 Cormier et al., 2016). For example, the reduction of contaminants introduced by land-based and marine activities are best addressed by the measures of their respective environmental protection regulatory frameworks (e.g. *Canadian Environmental Protection Act*) while the reduction of abrasion on a unique ecosystem component are best addressed by the measures used in marine conservation regulatory frameworks such as a marine protected area (e.g. *Oceans Act*). The integration should occur through the alignment of the expected outcomes of the two regulatory frameworks taking into account the causal relationship of the protection and conservation measures to achieve ecosystem and conservation objectives.

As part of an environmental protection regulatory framework, standards, codes of practices and guidelines specify the controls, procedures, and tasks that need to be implemented in the daily operations of a given activity to meet their conditions of license. Using farming, dredging and deep-sea mining activities to illustrate the above, a farming operation has to follow guidelines to reduce the level of sediments reaching an aquatic environment such as tilling reduction measures, contour strip cropping, and vegetative filter strips (#02 Cormier et al., 2018; #15 Creed et al., 2016). These protection measures are very different from the sediment control measures used for wharf maintenance or dredging activities such as the use of cofferdams and silt curtains to reduce the level of sediments released into the aquatic environment (#13 Cormier et al., 2016; Coker et al., 2010). The same can be said for the measures necessary for deep-seabed mining to ensure that the silt and sediments generated by the mining tool remains within the licenced area for this activity (#07 Cormier, 2019). Although the expected outcomes of these three regulatory frameworks would independently be considered as adequate to address their individual habitat sedimentation concerns, the effectiveness of their respective control measures would still release a residual level of sediments (#02 Cormier et al., 2018). Although these residual levels would still meet the respective conditions of licence, the collective residual levels of sediments from the three activities could ultimately exceed levels deemed acceptable to reduce the risks of sedimentation of marine habitats established by an environmental quality standard as a conservation strategy. In an ecosystem-based marine planning process, the planner would have to engage the regulators of these three sectors to identify where improvements could be made to their current regulatory frameworks to further reduce the respective residual levels of sediments reaching the aquatic environment. Although the respective industry sectors would be involved in such an exercise, it would be up to respective regulators to find a solution given that the industry would not be able to entertain changes to their practices outside their current regulatory obligations.

The above demonstrates the importance of the MSFD programme of measures (#08 Cormier et al., 2018). The directive seeks to "apply an ecosystem-based approach to the management of human activities" to ensure that their "collective pressures" are "kept within levels compatible with the achievement of good environmental status". Following the management logic of the controls listed in the programme of measures (Table 1), environmental protection regulatory frameworks for specific sectors would have to implement input controls and spatial and temporal distribution controls to meet the expected outcomes of the output controls to maintain and achieve good environmental status (#08 Cormier et al., 2018). In other words, the residual pressures of the individual environmental protection regulatory frameworks would have to implement standards, codes of practices and guidelines to influence the amount as well as where and when their activities would be allowed to meet the "degree of perturbation of an ecosystem component that is permitted" to maintain and achieve good environmental status of a given descriptor.

Table 1. Programmes of measures for the European Marine Strategy Framework Directive (Annex VI).

(1) **Input controls**: management measures that influence the amount of a human activity that is permitted.
(2) **Output controls**: management measures that influence the degree of perturbation of an ecosystem component that is permitted.
(3) **Spatial and temporal distribution controls**: management measures that influence where and when an activity is allowed to occur.
(4) Management coordination measures: tools to ensure that management is coordinated.
(5) Measures to improve the traceability, where feasible, of marine pollution.
(6) Economic incentives: management measures which make it in the economic interest of those using the marine ecosystems to act in ways which help to achieve the good environmental status objective.
(7) **Mitigation and remediation tools**: management tools which guide human activities to restore damaged components of marine ecosystems.
(8) Communication, stakeholder involvement and raising public awareness.

This would also imply that mitigation and remediation tools would be needed if the effectiveness of these regulatory frameworks are not able to meet the residual pressure permitted by the output control. This does not alleviate the challenges faced to assess the good environmental status as well as to establish the thresholds for the output controls (Berg et al., 2015). It does, however, highlight the need to develop tools to analyse the environmental protection regulatory frameworks as well as the science to conduct effectiveness studies of the standards, codes of practice and guidelines used in such frameworks (#02 Cormier et al., 2018).

3.2 Understanding mandates in marine planning and regulatory implementation

Managing the expectations of stakeholders within the mandate and scope of the planning process is a challenge for any planner that has to lead such processes (#15 Cormier et al., 2015). However, frustrations regarding the concerns expressed by stakeholders can also arise from the confusion as to the mandate and scope of the planning process and the authorities needed to implement the protection and conservation measures (#08 Cormier et al., 2018). Depending on the legislation, a planner may have a development or a conservation mandate that drives the context of the planning initiative and scopes the concerns that can be addressed by such initiatives. Managing expectations in a marine planning process has more to do with understanding the mandates set by the context and scope of the legislation used for that planning initiative. It is up to the planner to help those involved to understand why the process is being initiated, what concerns the process can consider and how the process can address these concerns.

However, anyone involved in marine planning initiatives also have to understand the subtle differences planning and public policymaking and regulatory implementation (#01 Cormier et al., 2017; Link and Browman, 2017). Most often discussed as governance (Boyes and Elliott, 2014), the parliamentary role of public policymaking establishes 'why' conservation, sustainability or development goals have to be reached while the management role of administrations determine 'what' has to be achieved through planning and the regulatory role of authorities have to determine 'how' to achieve it within their regulatory authority (Figure 1). In an ecosystem-based context, it is ultimately the environmental protection and conservation regulatory frameworks that manage human activities and their pressures to produce the expected outcomes needed to achieve the objectives of the plan and reach the goals established in public policy.

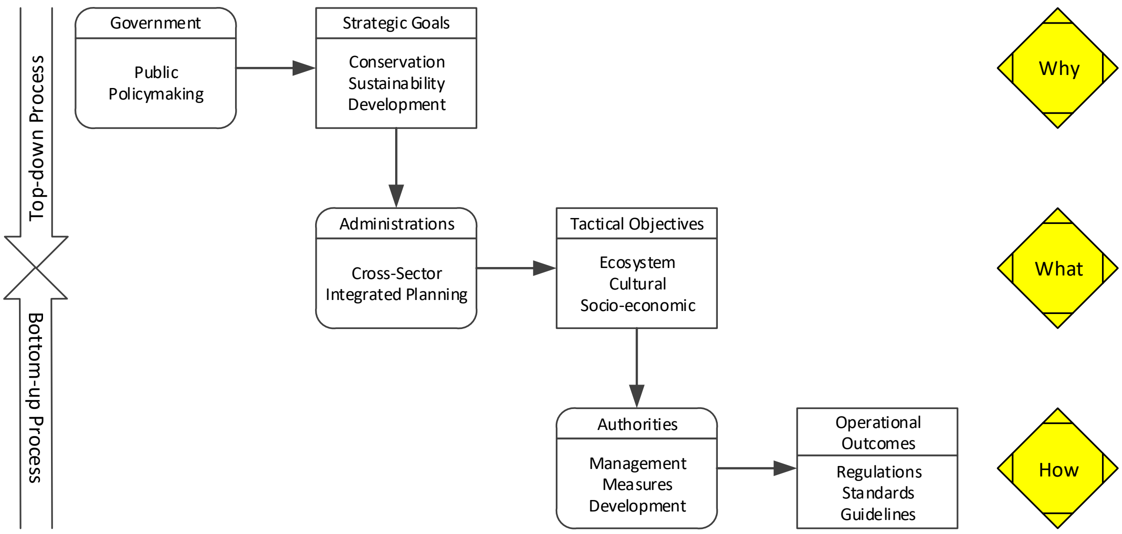


Figure 1. Operational ecosystem-based management (#01 Cormier et al., 2017).

Public policy is not strictly influenced by a national policymaking processes. National legislation is also influenced by international conventions and directives. Planners, regulators, stakeholders and even scientists have to understand that vertical integration of the goals and objectives of international conventions and directives are addressed through national legislation and their respective regulatory frameworks.

Figure 2 is simplistic representation of the vertical hierarchy of UN conventions, European directives, national legislation and sector regulatory frameworks. UN conventions and European Directives establish 'why' countries have to implement legislation to address these broader international goals and objectives. It is the signatories of these conventions or members of the European Union that are accountable for their implementation in national legislation. However, to enact the aspirations or directions from such international conventions and directives, it is the competent authority identified in national legislation that determines 'what' objectives citizens of a given country have to achieve and 'how' individuals and their activities will be managed and enforced through regulatory frameworks to implement those conventions and directives.

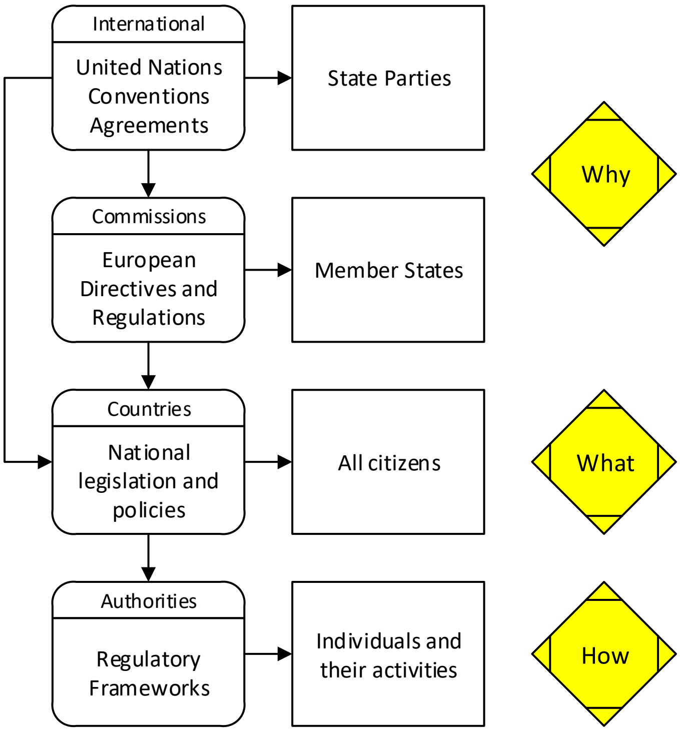


Figure 2. Vertical hierarchy of international, regional and national legislation.

This implies that national legislation and their environmental protection regulatory frameworks would be addressing the first target of the UN Sustainable Goal 14 for oceans regarding the need to prevent and significantly reduce marine pollution. It also implies that their conservation regulatory frameworks would be addressing the fifth target to conserve 10% of coastal and marine areas (#03 Cormier and Elliott, 2017). This is similar to Member States that are required to address the obligations of the European Directives through their national legislation and regulatory frameworks (Rätz et al., 2010). From a vertical integration perspective, the planner cannot integrate such conventions or directives unless these have been included in the legislation, policies or mandate provided by the respective government. It does provide insight as to the other jurisdictions that should be part of the planning process given that they would ultimately have to implement similar protection and conservation strategies (van Leeuwen et al., 2014).

Given that there could be a planner for each of the competent authorities involved in marine planning, a planner leading such complex initiative would have to horizontally integrate their plans to address the concerns of another planner. Although there are ongoing debates as to which of the MSPD or MSFD has the lead role in marine management (Brennan et al., 2014), each of these directives address very different goals and objectives. The goals of the Maritime Spatial Planning Directive is sustainable growth of maritime economies, development of marine areas and use of marine resources in contrast to the EU Marine Strategy Framework Directive which is to achieve and maintain good environmental status. Here, I explicitly spell out the MSPD to avoid confusion with marine spatial planning which is implied as conservation planning (Ansong et al., 2017; Calado et al., 2012; Schaefer and Barale, 2011).

Using the MSPD and MSFD as an example of two planners with very different mandates (Figure 3), each planner would lead their planning initiative independently from one another because of the different context and scope provided by the two directives (#08 Cormier et al., 2018). Each planner has very different mandates as to 'why' the planning initiative is needed as well as 'what' each would be planning for (e.g. sector based versus environmental concerns) as well as 'how' the plan would be implemented (e.g. spatial allocation to address health, safety and conflicts among users versus a programme of measures for good environmental status).

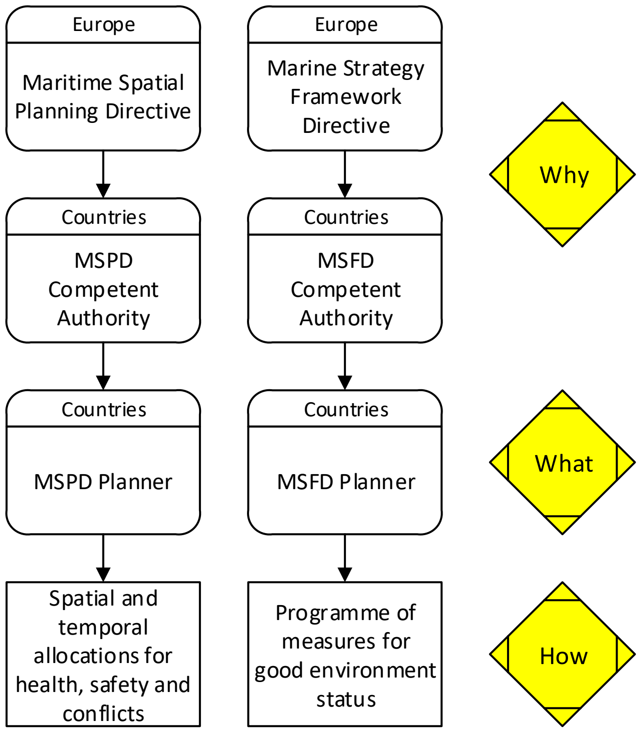


Figure 3. Horizontal relationship between the purposes of the MSPD and MSFD.

The need for horizontal integration between these directives comes from the MSPD that stipulate that the ecosystem-based approach of the MSFD will be used to reduce the collective pressures from the human activities being planned under the MSPD to achieve good environmental status. Thus, the two planners would have to coordinate their planning activities as well as the relevant regulators and stakeholders to align the environmental protection regulatory frameworks of the human activities of the MSPD with the expected outcomes of the programme of measures of the MSFD (Figure 4). As mentioned in Section 3.1, additional standards, codes of practices and guidelines could be needed as part of the sectors environmental protection regulatory frameworks in order to address the programme of measure of the MSFD (#04 Cormier et al., 2019).

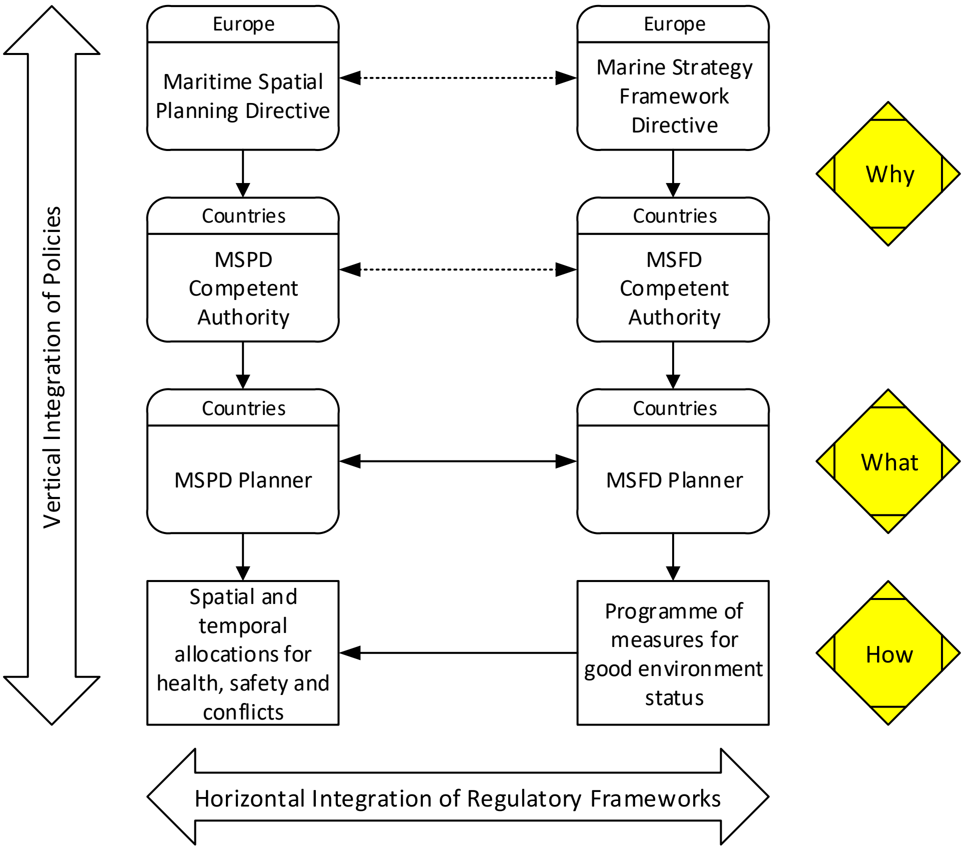


Figure 4. Implementation of the ecosystem-based approach to management through horizontal integration of regulatory framework.

Although this provides insights as to how national legislation and regulatory frameworks are nested within international conventions or directives (Raakjaer et al., 2014), this section also highlights that one competent authority cannot plan everything or every concern from within the mandate provided and that horizontal integration in marine planning has more to do with coordination among other competent authorities that are also planning from within their mandate (van Hoof et al., 2014). This is also exacerbated by the need for transboundary coordination with other jurisdictions (Marshak et al., 2017).

Each marine planning situation has their own institutional, legislative and regulatory impediments that can only be addressed through planning, coordination and analysis (van Leeuwen et al., 2014, 2012). They either have to abide by the directives such as in the European situation or collaborate with other jurisdictions such as the case in Canada with the *Oceans Act*. Although the *Oceans Act* has jurisdiction over all marine waters and has marine protected area authorities, it still has to facilitate an integrated coastal and oceans management process with other jurisdictions to reduce the 'collective pressures' that cannot be addressed by conservation strategies alone. Besides the authorities of marine planning in national waters (Maes, 2008), the UNCLOS relies on the member countries to regulate activities in areas beyond national jurisdictions as is the case for deep-seabed mining (Lodge and Verlaan, 2018). Although the International Seabed Authority can develop regulatory requirements for exploration and exploitation of marine physical resources as well as designate areas of particular interest for conservation purposes, the actual operational implementation of the requirements still depends on the Contracting Parties. Although the legislative context and scope is key to ensure that a marine planning initiatives does not lose sight of their purpose, it is the regulatory implementation of the protection and conservation measures that is required to ensure that human activities and their pressures are managed to achieve ecosystem outcomes across these planning initiatives. Objectives and good intentions cannot by themselves "carry into effect" the policy goals and objectives (#01 Cormier et al., 2017; Nøstbakken, 2008; Rife et al., 2013)

3.3 Understanding the subtle differences between goals, objectives and outcomes

Section 3.1 implies that the objectives and the expected outcomes of the protection and conservation regulatory frameworks need to be specific and explicitly provide an unambiguous explanation of the expectations. However, conventions, legislation, and policies do not always provide clearly delineated and enunciated goals, objectives and outcomes. Although the analysis of legislation and regulatory frameworks mentioned above may seem daunting, such an analysis should be conducted at the onset of the marine planning initiative to understand the legislative, regulatory and policy context of the human activities that need to be planned, to assess the ecosystem, cultural, social and economic vulnerabilities related to the pressures generated by these activities, to analyse the effectiveness of the protection and conservation measures to reduce these vulnerabilities, and to avoid producing a plan that cannot be implemented within the legislative and regulatory authorities of the jurisdictions involved (#06 Cormier and Kannen, 2019; #12 Cormier et al., 2015). However, an analysis of legislation, regulations and policies is more than simply making a list.

In policymaking, ambiguous goals and objectives can lead to a misunderstanding of the mission, the direction and the priorities of an organization's policies (Chun and Rainey, 2005). Ambiguity subsequently carries through to the indicators used to monitor the effectiveness of the implemented operational controls and the evaluation of the performance of the plan in achieving its objectives (Behn, 2003). Operational controls are the tasks and procedures implemented in the daily operations of an organization including monitoring, verifications, and maintenance (Osselton and Heuts, 2016). Lessons from the schools of management tell us that goals are to be considered as long-term future aspirations setting the values, principles and rules in the selection of means and objectives in shorter-term planning initiatives (Ackoff, 1990). Once the policy goals and objectives are established by an organization, there should be as much attention given to setting the expected outcomes for the operational controls that are selected to achieve these objectives in the immediate term (Hupe and Hill, 2016). In summary, policymaking establishes the goals that sets the context for developing objectives in planning and the objectives sets the scope of the expected outcomes for the operational controls in implementation (Anderson, 2011; Anthony and Dearden, 1980).

Once implemented, the performance of a plan is evaluated from indicators used to monitor and verify the effectiveness of the operational controls in producing the expected outcomes as a measurement of the objectives to be achieved (Wilson and Pearson, 1995). That implies that expected outcomes and objectives have to be specific, measureable, achievable, realistic, and time-bounded (SMART) in order to develop appropriate indicators to monitor the effectiveness of the controls against the expected outcomes needed to achieve the objectives (Hoyle, 2009). In marine planning and management, this implies that sustainable development and the conservation of biological diversity are the long-term goals that sets the environmental, cultural, social and economic context for the objectives to be achieved in the shorter-term and scope the expected outcomes of the protection and conservation measures to be implemented in the immediate term. Understanding the hierarchy of goals, objectives and outcomes as described above highlights the importance of the expected outcomes of the protection and conservation measures to operationalize ecosystem-based management (#01 Cormier et al., 2017). Without understanding how human activities are to be managed in the immediate term, it would not be possible to ascertain if objectives are being achieved given that the monitoring of the expected outcomes are a measure of effectiveness.

Likely a part of human nature, planners, scientists, stakeholders or anyone involved in marine planning most often start to discuss the assessment of impacts based on their perceived concerns. These concerns are most often based on the assumption that environmental protection measures are not effective or not existent or that a marine protected area is the only solution without having analysed the evidence of their perception of the problem nor the effectiveness of such measures. Because of this, many marine planning processes end up to little or no avail even though these processes were supported by the best science available and by the best intentions of those involved (Cobb et al., 2008; Collie et al., 2013; Hardy and Cormier, 2008; McCrimmon and Fanning, 2011; McCuaig and Herbert, 2013). Although governance, stakeholder engagement and scientific uncertainty are most often advocated as impediments to such process (Cavallo et al., 2019; Jessen, 2011; McCrimmon and Fanning, 2011; Stephenson et al., 2017), in practice it is the lack of understanding the hierarchy of goals, objectives and outcomes that is typically found in relevant environmental legislation and policies that is the impediment to the progress of marine planning (Gavaris, 2009; Grumbine, 1994; Katsanevakis et al., 2011; Murawski, 2007).

Without a good knowledge of their planning legislation and policies, planners often start developing objectives in consultation with stakeholders and scientists without an analysis of their own policies. Given the best intentions, goals, objectives and outcomes end up as reworded versions of the ones already established in their legislation and policies or are inadvertently omitted creating more ambiguity and confusion during the planning process (Quental et al., 2011). In addition, a planner can also spend valuable resources and time developing planning processes instead of getting to the tasks at hand (#12 Cormier et al., 2015). This produces endless discussions regarding wording for text that stifles the efforts for getting to the specific concerns of the planning processes at hand. This ultimately leads to a loss of credibility, disengagement, and stakeholder fatigue (#06 Cormier and Kannen, 2019; Hendriksen et al., 2014; Röckmann et al., 2015). A lack of specificity in objectives and expected outcomes can also lead to scope creep that ultimately undermines the planning process spawning endless assessments, studies and consultations (#06 Cormier and Kannen, 2019; #12 Cormier et al., 2015). Ultimately, this can lead to marine plans that are unlikely to produce effective management strategies or that cannot be evaluated (Domínguez-Tejo and Metternicht, 2018).

Conducted with the participation of the stakeholders and scientists, an analysis of legislation and policies would help frame the discussions regarding the concerns expressed and the evidence needed to address these concerns within the scope of the legislation and policies (#12 Cormier et al., 2015). It shifts the discussion from ‘why’ this planning process is important to ‘what’ we need to consider in the plan and ‘how’ will the plan be implemented. It also helps everyone involved to understand what the plan can do and what the plan cannot do given the authorities provided by the legislation and regulatory frameworks.

For discussion purposes, Table 2 shows that sustainability, conservation and growth are the goals that are most commonly found in marine environmental policies even though the wording may be different.

Table 2. Examples of goals, objectives and the expected outcomes of measures extracted from legislation and policies.

Legislation and Policies	Goals (WHY)	Objectives (What)	Expected outcomes of the protection and conservation measures (How)
FFHPP (DFO, 2019a)	Provide a framework for the conservation and protection of fish and fish habitat	Regulate works, undertakings and activities that could result in harmful impacts to fish and fish habitat	• Avoidance of measures to prevent the harmful impacts to fish and fish habitat • Mitigation measure to reduce the spatial scale, duration or intensity of the harmful impacts to fish and fish habitat • Offset address the residual impacts after efforts made to avoid and mitigate harmful impacts to fish and fish habitat
UNCLOS	…peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment…	Article 145: Prevention, reduction and control of pollution and other hazards and of including the coastline, to the marine environment, interference with the ecological balance of the marine environment	Annex III Article 17: • Rules, regulations and procedures shall be drawn up in order to secure effective protection of the marine environment from harmful effects directly resulting from activities in the Area or from shipboard processing immediately above a mine…
MSFD	…thematic strategy for the protection and conservation of the marine environment has been developed with the overall aim of promoting sustainable use of the seas and conserving marine ecosystems	Article 1: …achieve or maintain good environmental status in the marine environment… Annex I: Qualitative descriptors for determining good environmental status	Annex VI: Programmes of measures • Input controls: management measures that influence the amount of a human activity that is permitted • Spatial and temporal distribution controls: management measures that influence where and when an activity is allowed to occur • Output controls: management measures that influence the degree of perturbation of an ecosystem component that is permitted
MSPD	Article 1: … sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources…	Article 5: …contribute to sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts…	Article 8: • …identify spatial and temporal distribution of relevant existing and future activities and uses in their marine waters, in order to contribute to the objectives set out in Article 5. • …shall take into consideration relevant interactions of activities and uses…

Depending on the legislation and policies that drive a planning or regulatory process, objectives and even the expected outcomes for the measures can sometimes be found in the legislation and policies. However, one has to understand that the scope of these objectives and expected outcomes are not the same given the context of the legislation. Using the Canadian *Fisheries Act* (Canada, 2019b) and the Fish and Fish Habitat Protection Policy Statement (FFHPP) (DFO, 2019a) as an example, the context is the protection of fish and fish habitat to ensure the productivity of relevant fisheries within the scope of harmful impacts resulting from a work, undertaking or activity occurring near or in water. Although UNCLOS applies to areas beyond national jurisdiction, the context and scope are somewhat similar in terms ensuring effective protection of the marine environment from harmful effects resulting from mining activities in the Area or from shipboard processing immediately above a mining area. However, the context and scope of the MSFD requires that good environmental status be achieved through the implementation of the programmes of measures to reduce the collective pressures of many marine activities and land-based sources. In contrast, the context and scope of the MSPD is to promote sustainable growth, development and use of marine resources through spatial and temporal allocations of marine activities. The former are environmental protection regulatory frameworks for the proponent of a project while the latter applies to a planning process for multiple activities, their pressures and conflicts managed by several regulatory frameworks.

From a regulator's or planner's perspective, the 'why' such processes should be undertaken is less of a preoccupation than 'what' can be considered and 'how' to implement it. As a regulator working within the context of the Canadian fish and fish habitat provisions of the *Fisheries Act*, the death of fish and any temporal or permanent change to fish habitat that is likely to result from 'a' work, undertaking or activity is 'what' needs to be considered while avoidance, mitigation and offsetting measure is 'how' the requirements of the *Act* is to be implemented. As a planner working within the context of the MSFD, the collective pressures that could undermine the relevant descriptors of good environmental status as a result of many human activities is 'what' needs to be considered while the programmes of measures is 'how' the Member States of the European Union will manage their activities through their national legislative and environmental protection regulatory frameworks.

Although these objectives and expected outcomes would be considered to be specific, their scope of application is very different in terms of the scale of the activities to be managed as well as their ecosystem effects and impacts. In the Canadian situation, it is the harmful impacts to fish and fish habitat that have to be managed within the footprint of a work, undertaking or activity. Here, the regulator has to develop avoidance, mitigation and offsetting measures implemented as standards, codes of practice and regulations as requirements for individuals and their projects near or in water. In the case of the MSFD, it is the collective pressures and impacts generated by human activities in a regional sea context that would have to be managed through national legislation and environmental protection regulatory frameworks. Here, the planner has to deal with the additional complexity of multiple regulators to manage which pressure and activity to achieve good environmental status. There would likely be a situation that one or more regulators inside or outside the planning area may have to change or develop new standards, codes of practice or regulations to address the requirements of the programme of measures to achieve good environmental status. Thus is the key difference between the role of the planner and the role of the regulator from an ecosystem-based management approach.

Any integrated oceans management or marine spatial planning process should start with an analysis of the legislation and policies that provides the impetus to initiate such a process (#07 Cormier, 2019; #08 Cormier et al., 2018; #13 Cormier et al., 2016). Subsequently, it should include an analysis of the environmental protection regulatory frameworks used to manage human activities and their pressures that have been identified during the planning as having the potential to undermine the plan's objectives. This should also be conducted within the context of the conservation strategies being considered by the plan. It would also avoid the pitfall of having a marine plan that is well supported by stakeholders from getting mired into legislative impediments at implementation (Link et al., 2018). It would help understand what can be and what cannot be managed by current legislative and regulatory frameworks including who would has to implement the improved or new requirements (Newton and Elliott, 2016). It should help improve the expected outcomes of the regulatory frameworks used to manage human activities as a means to better integrate these with conservation strategies (#04 Cormier et al., 2019).

3.4 Understanding the role of scientific advisory processes in policy

In most legislative context a planner or a regulator seldom use scientific literature for decision-making without asking for advice. There are several reasons for this. For example, they may not be aware of the latest papers published on a given subject matter; they may not be aware of the various scientific views regarding a given topic; they may not have the background needed to understand the papers or simply do not have access to scientific literature – most often their organization does not subscribe to scientific journals. Although scientists advocate the need for managers to be more knowledgeable of the natural sciences and marine ecology, the fact that most managers involved in multiple environmental programs should also be more knowledgeable of law, economics, social sciences, anthropology, management, administration, enforcement, communication, and so on. This highlights the reality that a manager or a planner has to rely on information from a broad range of disciplines in planning and regulatory processes and, therefore, must rely significantly on the advice from experts in these disciplines.

Given the wide range of ecosystem data, models and knowledge used in planning, a planner has to rely on scientific and technical advisory processes to peer review the science to be used as evidence for policy advice. These processes are very different from a peer-review process for an article submitted to a journal that is done to ensure the quality of the work being published. However, the science needed to inform public policymaking in contrast to the advice requested in planning and regulatory processes are not the same (Figure 5).

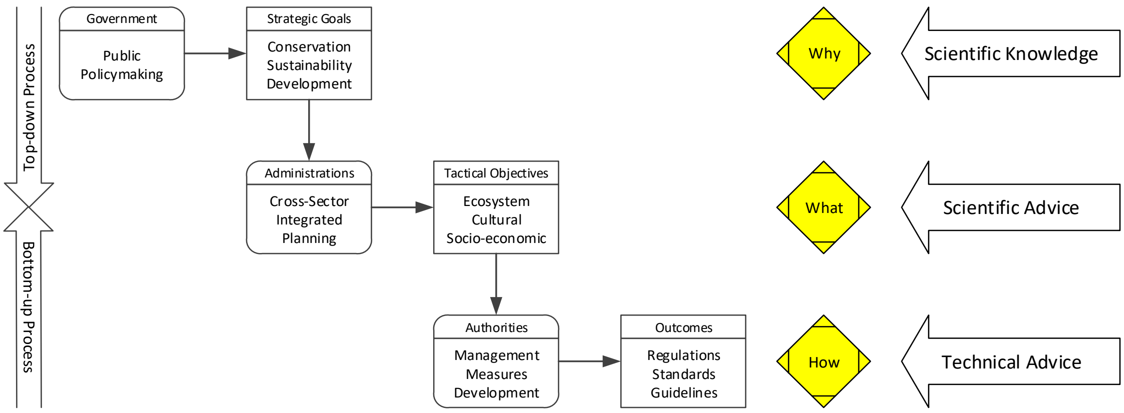


Figure 5. Science input in policy, planning and regulatory frameworks (#01 Cormier et al., 2017).

In public policymaking, parliamentary and political systems are informed via multiple channels from public opinion to interest groups regarding a broad range of policies and strategies (Fredriksson et al., 2005; Howlett and Newman, 2010). Scientific knowledge regarding a particular issue is mostly provided to determine 'why' a given policy is needed. These may be informed by published literature that are brought to the attention of the policymakers or through formalized advisory processes such as the US National Academy of Science or the Intergovernmental Panel on Climate Change. Initiated by governments and international organizations, these advisory processes provide independent objective advice to policymakers regarding policy implications of a scientific and technological nature. As a key aspect of the science-policy interface (Gluckman, 2016; Howarth and Painter, 2016), the advice reflects the peer review process of the science in reaching a consensus on how to formulate the advice. Outputs such as world oceans assessments and global warming are examples of such processes. Although considered by policymakers as a valuable contribution to policymaking, the decisions may not always correspond to the advice provided because of other public policy considerations (Hutchings and Stenseth, 2016; Pouyat, 1999).

In marine planning, science advice can be more complex when a planner has to identify 'what' should be considered in terms of environmental, cultural, social and economic considerations at hand and the concerns expressed by the stakeholders (Figure 5) (Quirion et al., 2016). This requires formalized institutional advisory processes that are tightly linked to the context and scope of the legislation and policies that are driving the planning process (Imperial, 1999; Walther and Möllmann, 2014). The advice being sought will be much more specific in planning than for public policymaking (Elliott et al., 2018). The International Council for the Exploration of the Sea Advisory Committee and the Canadian Science Advisory Secretariat are examples of such formalized processes (Rice, 2019). Compared to policymaking, the scientific advice such as fisheries stock assessments, ecosystem impacts and effects or species recovery plans are direct inputs to administrations mandated to take management decisions. In a regulatory context, the advice is even more focused as it has to determine 'how' to manage a situation to produce expected outcomes of the management measures being considered for implementation such as the standards, codes of practice or guidelines to be used in environmental protection and conservation strategies (#01 Cormier et al., 2017; #02 Cormier et al., 2018). Here is where the science-policy interface switches to a policy-science interface, albeit a management-science interface where management is asking for more technical advice taking into account scientific, management and operational uncertainties (DFO, 2014a). In the vast majority of the cases, the decision is not simply a matter of stopping activities or their pressures given the dynamics of marine ecosystems and their responses to the pressures from human activities.

The challenge when formulating advice from empirical science is the need for scientists to judge the evidence and reach a consensus to formulate advice that is independent and impartial from bias either from the research itself or personal convictions (Rice, 2011; Rose and Parsons, 2015). Data, models and methods are not the advice as it is the evidence needed to formulate the advice that needs to be interpreted by managers, planners and stakeholders that may not have the technical expertise to understand the science let alone judge the science (Lackey, 2007). However, this does not imply that scientists should not advocate preferences as to the decisions to be made as long as they are transparent in their positions (Schmidt, 2015). When advocating what should be done, scientists also have to understand that the debates and consensus shifts from a scientific peer-reviewed forum to a public one (Apitz et al., 2017; Gauchat, 2012).

Although one could argue that science advisory processes may not always produce the best advice, independent and impartial peer-reviewed policy advisory processes are the best we can do given the uncertainties underlying any scientific information used as evidence for policy, management or regulatory advice (de Kerckhove et al., 2015). Confirmation bias can easily happen with simulations, models and indicators as they can be easily confused as reality (Dickey-Collas et al., 2014; Rochet and Rice, 2009; Schnute and Richards, 2001). As scientists, we may be able to deal with the scientific uncertainties while formulating the advice. However, managers, planners and stakeholders do not necessarily have the technical background to ascertain such uncertainties and can take the outputs of the scientific literature at face value (Hedeholm et al., 2016; Rozema et al., 2012). However, the knowledge generated may not always be usable for the decisions that have to be made (Haas, 2004).

Not all can be accomplished in one science advisory process. There may be a need for a subsequent advisory processes that build upon the evidence that was examined in previous advice. Although ecosystem-based approaches to science has been around for a few decades, the formulation of policy advice has not yet reached a normative stage. With the advent of the ecosystem-based approach in the late 1990's, it took a number of Canadian advisory processes to establish ecosystem objectives from a policy perspective to criteria for identifying ecologically and biologically significant areas and species as well as ecosystem overview reports (DFO, 2004, 2005, 2006). As integrated oceans management continued to evolve and advance, further advice was provided regarding conservation objectives and bioregional boundaries (DFO, 2007a, 2009d). The emerging need for a more comprehensive conservation strategy spawned advisory processes to provide guidance on the development of marine protected area networks and representativity (DFO, 2012b, 2011a). With the expanding need to understand the role of environmental protection strategies, the criteria for ecologically and biologically significant areas species were reviewed as to their applicability in such context (DFO, 2011b) including the identification of other effective area-based conservation measures (DFO, 2016). Other advisory processes were undertaken to integrate risk management and assessment approaches in freshwater and marine ecosystem-based management and regulatory processes (DFO, 2015a, 2014b).

The advisory reports cited are not intended to be an exhaustive list of advice provided over the years. They show a long history of normative science advice that built upon previous advisory processes as management needs changed and science advanced. Today, such a library is proving valuable as a reference of past advice to avoid starting new processes for roughly the same questions. These advisory processes are also important as they identify future management concerns or questions that can help develop forward looking scientific research agendas.

4 Reducing the uncertainties of achieving policy objectives

In the previous sections, the integration of environmental protection and conservation strategies are discussed as a means to implement ecosystem-based management through regulatory frameworks. It also discussed the need to establish the context and scope of the legislation and policies that will be driving a marine planning process including an analysis of the environmental protection and conservation regulatory frameworks that will be used to implement the resulting plan. More importantly, it highlighted the need to establish the context and scope for the planning process before initiating any environmental or ecosystem assessments. As mentioned earlier, a risk assessment initiated out of context and scope is nothing more than an assessment of the perceived risks of the person doing the assessment (#07 Cormier, 2019). In risk management, the output of the risk assessment is an evaluation of the effectiveness of the management controls that could be implemented to achieve a given objective. This subsequently implies that the output of a marine planning process should be a decision regarding the environmental protection and conservation measures needed to achieve their objectives (#11 Cormier et al., 2013; #12 Cormier et al., 2015).

Current design and approaches for marine planning processes differ greatly from one another. Some are ecosystem-based or sector-based while others are predominantly preoccupied with governance, transboundary coordination or strategic policy (#09 Elliott et al., 2017; Ehler et al., 2019). Few marine planning processes consider the environmental protection and conservation regulatory frameworks that are already managing marine activities and their pressures in the marine environment (#01 Cormier et al., 2017). A plan listing objectives is only a plan unless it outlines and describes the outcomes of the measures that are needed to achieve the objectives. Given the range of objectives to be achieved and management measures to be implemented, a risk management approach to planning adds the need to assess current management practices in light of the diversity of objectives to be achieved (#06 Cormier and Kannen, 2019; #12 Cormier et al., 2015). The risk management standard of ISO 31000 provides a generic framework and structured policy driven process that lends itself to the diverse objectives and regulatory frameworks that are involved in marine management. Furthermore, it also provides a lexicon of definitions and risk assessment tools that can help improve some of the confusion in the jargon currently used by anyone involved in ecosystem-based and marine planning processes from a risk perspective (#01 Cormier et al., 2017; #15 Creed et al., 2016). This section discusses the key findings in bridging marine planning and ecosystem-based management concepts with these standardized approaches.

In 2009, the ISO 31000 risk management standard was published by the International Organization for Standardization with the intent of resolving many inconsistencies and ambiguities that existed between different risk management and assessment approaches and was revised in 2018 (Purdy, 2010). The standard establishes the definition of risk as the effect of uncertainty on objectives and requires that the effectiveness of the current controls (e.g. management measures) be assessed to determine how best to treat the risks to reduce the uncertainties of achieving those objectives. The purpose of a risk management process has more to do with the management options to reduce the risk instead of an assessment of the severity of the consequences of risk. Furthermore, a risk management process does not decide ahead of time what should be managed nor how it should be managed such as in the cases where marine protected areas are most often considered first in the absence of an understanding of current environmental protection regulatory frameworks. This decision is made from the outputs of the risk assessment process. As an additional consideration, the adoption of such a standard can also reduce the human and financial resources needed to develop a risk management process let alone a risk-based marine planning process from scratch.

In this section (Figure 6), the risk management process of ISO 31000 is introduced from an ecosystem-based management context. The left side of Figure 6 is the flow diagram of the risk management process of the standard. The pictograms to the immediate right of the flow chart depicts the Bow-tie analysis and risk matrix tools to demonstrate how these techniques can structure the management problem and evaluate the management options.

As a short summary, the risk management process is initiated by first establishing the policy context, scope and risk criteria used to frame the risk assessment. The risk assessment starts with risk identification of the tangible and intangible sources of risk that could have an effect on the objectives as well as the mechanisms that could cause an event of concern and the consequences of such an event. Risk analysis involves a qualitative or quantitative analysis of the likelihood of an event of concern and the nature and magnitude of the consequences of such an event. As part of the risk analysis, the effectiveness of existing management measures are also analysed in terms of their capacity to reduce the likelihood of an event or the magnitude of the consequences of such an event. In contrast, common environmental and ecosystem risk assessment techniques seldom include such an assessment of the measures (#10 Astles and Cormier, 2018; #17 Gimpel et al., 2013; #18 Aps et al., 2018). Risk evaluation is the decision point for managers and stakeholders where the effectiveness of various management scenarios are compared to determine how best to reduce the risks of not achieving objectives. Risk evaluation is where the causes of an event, the likelihood of an event and the magnitude of the consequences are translated back into the policy that establishes the severity in terms of impacts and harm. Risk treatment is basically the selection of the suite of measures needed to implement the management scenarios chosen during the risk evaluation by managers and stakeholders. Subsequently, monitoring activities are ultimately implemented to generate the necessary data and information to review the performance of the management scenario and ascertain where improvements could be introduced in the future. The entire process is conducted in consultation with regulators, stakeholders and scientists including the public. Thus, the risk management context, scope and criteria establishes ‘why’ the process is being initiated, the risk assessment determines ‘what ‘needs to be managed to reduce the uncertainty of not achieving an objective and risk treatment is ‘how’ the risks are to be reduced.

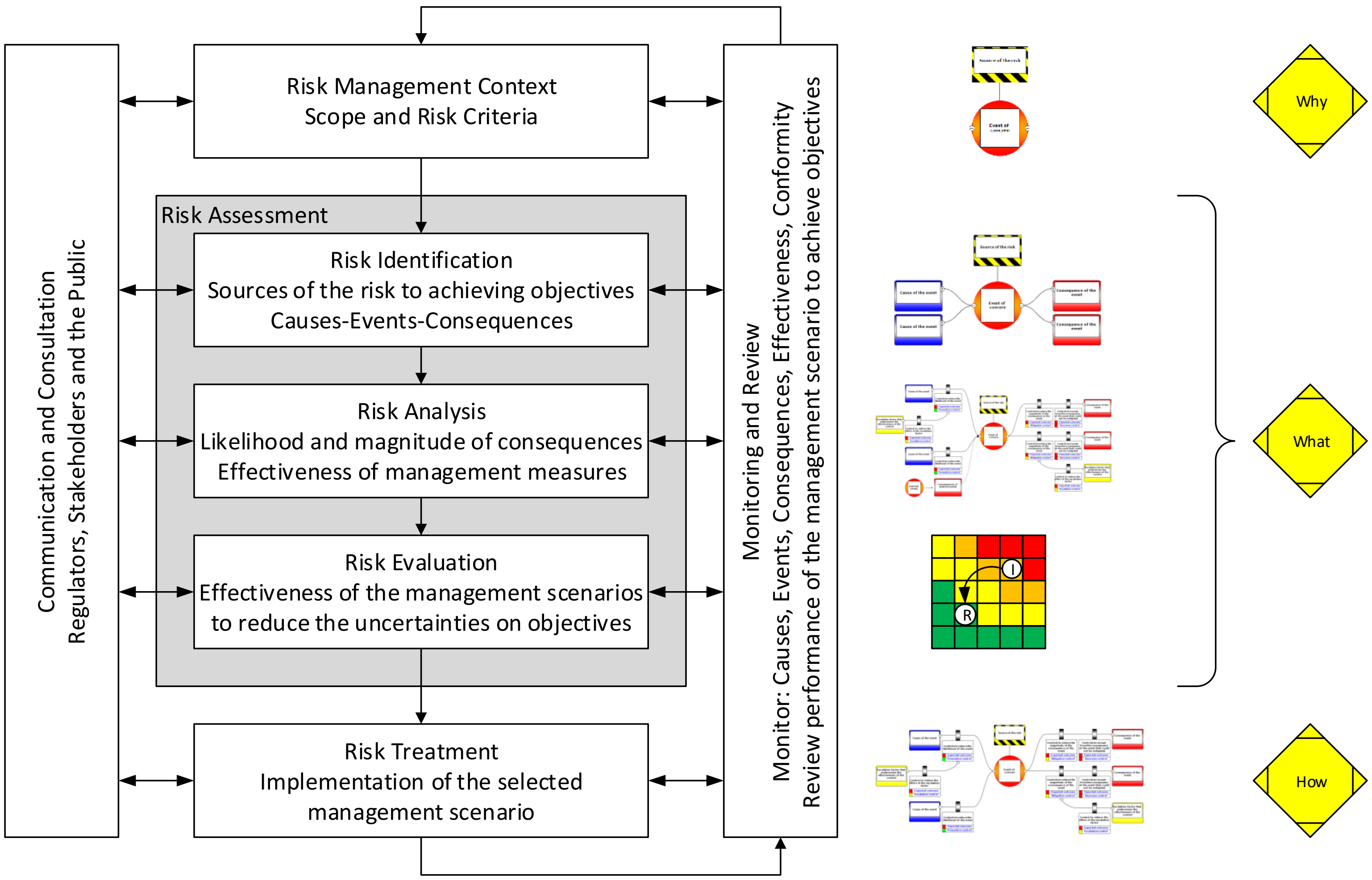


Figure 6. ISO and IEC risk management processes and tools

4.1 Tools for horizontal integration of prevention and conservation management strategies

When working with regulators, stakeholders and scientists, it is always difficult to structure the management problems to be resolved because of the diverse amount of information brought to the planning table. Given that most people involved in such processes have very different levels of technical backgrounds, it is very easy to get confused as to how policy, stakeholder concerns and scientific inputs all fit together. The IEC 31010 (IEC, 2019) provides more than 30 qualitative and quantitative risk assessment techniques to support the risk management process of ISO 31000. Given the need to analyse the effectiveness of the management measures, the Bow-tie analysis is one of the three controls assessment techniques of IEC 31010. It also provides a valuable visual representation of the risk management scenario to communicate and understand the issues with everyone involved. As with ISO 31000, the ecosystem-based management context was adapted to the normative requirements of the Bow-tie analysis while ensuring that the interpretations and use of the technique adheres to the definitions of that standard.

There are three controls assessment techniques provided by IEC 31010:

a) **Bow-tie analysis** is used to analyse the effectiveness of prevention controls of the multiple causes of an event and the mitigation and recovery controls of multiple consequences of such an event. This technique lends itself better to an ecosystem-based management context because it can deal with multiple causes of environmental impacts and effects. It can also integrate multiple environmental protection and conservation regulatory frameworks as well as integrate external factors such as natural variation and the effects of climate change (#04 Cormier et al., 2019).
b) **HACCP** is used to analyse food safety hazard to determine where along a processing line critical control points should be introduced to reduce the occurrence of such hazards in food products. This technique is less applicable to an ecosystem-based management context because it is primarily focused on the analysis of one food hazard and its critical controls points at a time (#19 Cormier et al., 2007). It does not lend itself well to multiple hazards and their

consequences that are managed through a hierarchy of mitigation measures (Arlidge et al., 2018).

c) **Layers of protection analysis (LOPA)** is used to analyse a cause-consequence pair to determine whether a risk is controlled to an acceptable level. It is a semi-quantitative tool for analysing risk using rules and orders of magnitude estimates of frequency, probability and consequence severity (Baybutt, 2014a; Blanco, 2014). This technique has the potential to complement a Bow-tie analysis as does Bayesian quantitative approaches (Markowski and Kotynia, 2011).

The Bow-tie analysis was developed by the petrochemical industries in the 1980’s to manage health and safety hazards in industrial processes (de Ruijter and Guldenmund, 2016). It is mainly a qualitative approach to the analysis of the controls that can be supplemented by quantitative tools such as Bayesian Belief Networks (Badreddine and Amor, 2013; Khakzad et al., 2012; Pitblado and Weijand, 2014). It can incorporate the LOPA approach as mentioned above or as a combination of a fault tree and event tree analysis used in engineering (Markowski and Kotynia, 2011). However, it is the graphical representation of risks and their management scenarios that are proving to be most valuable to help managers and stakeholders understand the risks and how they are managed (Saud et al., 2014).

Currently, the Bow-tie analysis has been used and introduced in a broad range of freshwater and marine environmental policy and management contexts (#02 Cormier et al., 2018; #04 Cormier et al., 2019; #05 Cormier and Lonsdale, 2019; #07 Cormier, 2019; #08 Cormier et al., 2018; #09 Elliott et al., 2017; #10 Astles and Cormier, 2018; #13 Cormier et al., 2016; #14 Cormier, 2019; #15 Creed et al., 2016; Kishchuk et al., 2018; Smith et al., 2016) as well as stakeholder engagement in coastal risk management processes (Gerkensmeier and Ratter, 2018).

The Bow-tie diagram structures the relationships between the source of the risk, the causes of an event of concern and the consequences of such an event Figure 7.

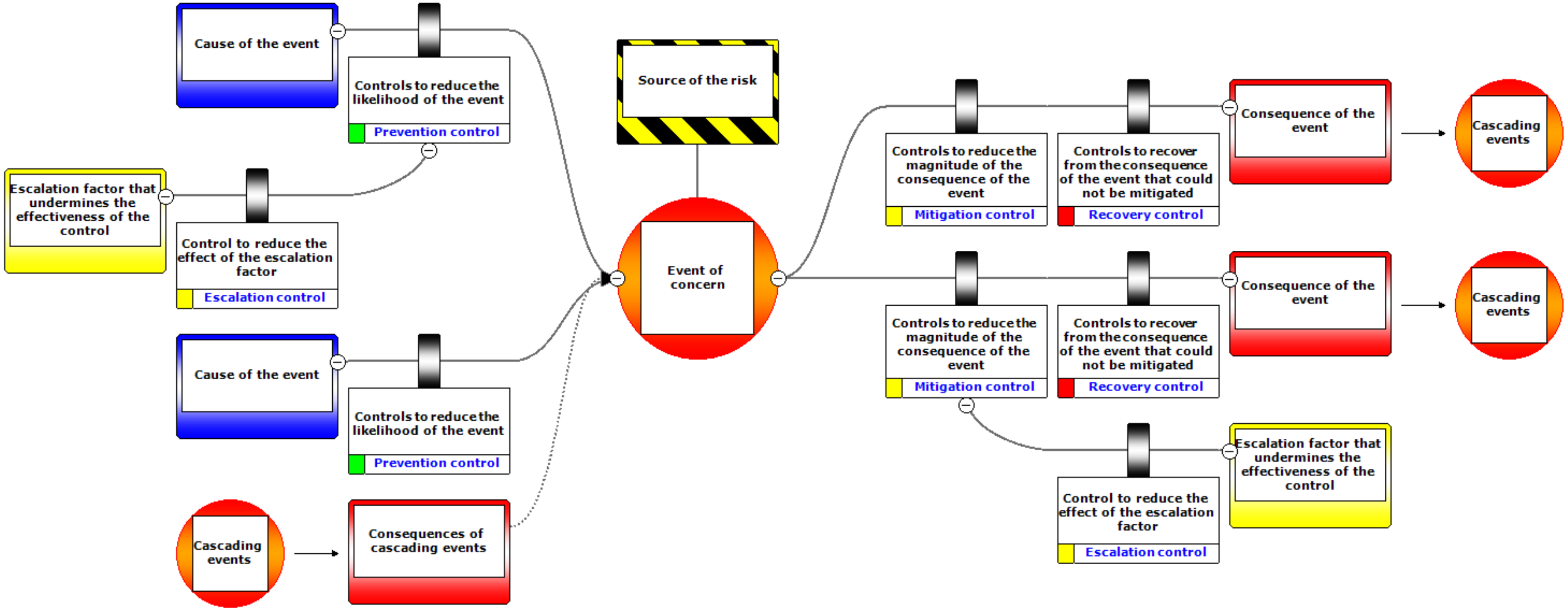


Figure 7. Bow-tie analysis diagram (BowTieXP v9.2.17).

The centre of the Bow-tie represents the relationship between the source of the risk or a hazard (Yellow striped box) to the event of concern that could occur (Central circle). On the left side of the Bow-tie, the causes (Blue boxes) represent the mechanisms by which the event of concern could occur because of the source of the risk. The right side of the Bow-tie represents the consequences (Red boxes) that could occur if and when the event of concern happens. The true purpose of the analysis is to identify the prevention controls of the causes to reduce the likelihood or the probability of the event occurring and to identify the mitigation controls to reduce the magnitude of the consequences and the recovery controls to recover from the consequences that could not be mitigated. In addition, the Bow-tie is also used to identify the escalation factors (Yellow boxes) that could undermine the effectiveness of any of the prevention, mitigation and recovery controls. In such cases, additional escalation controls for each escalation factor would be needed to reduce the likelihood of undermining the effectiveness of the given control. However, the consequences of cascading events occurring outside the span of the prevention control can directly trigger the event of concern (Red box on the lower left). In such situations, the prevention controls are not effective at reducing the likelihood of the event of concern and only mitigation and recovery controls can be implemented to deal with the consequences. In cases where the effectiveness of the mitigation and recovery controls are not effective, the consequences of this Bow-tie can, in turn, cascade into a subsequent event (Circles to the far right). Thus, the Bow-tie analysis can chain multiple Bow-ties events and consequences as a pathway of cumulative risk.

Each individual Bow-tie represents a management system of prevention, mitigation and recovery controls or one management scenario. A Bow-tie can only manage their causes and consequences. This implies that the consequences of a cascading event (Red box on the lower left) or the consequences from this Bow-tie cascading into a subsequent event (Circles to the far right) can only be managed by their respective management system (e.g. Bow-ties). The management system of prevention controls (Left side of the Bow-tie) is considered to have 'lost controls' if the event occurs forcing management to address the consequences through mitigation and recovery controls. It is an indication that the prevention controls are not effective at managing the causes. Zero risk can only be achieved by removing the source of the risk (Yellow striped box). As long as the source of the risk is present, there is always the likelihood that the event can occur because the prevention controls can never be totally effective (Figure 8). Based on the Swiss cheese model, each individual control or barrier to risk are not fail-proof where a series failures can allow the hazard to cause losses.

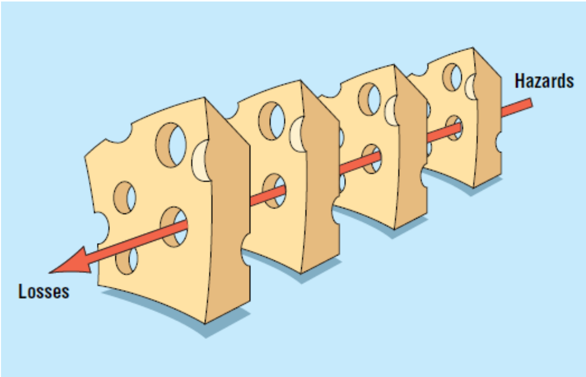


Figure 8. The Swiss cheese model showing why controls and barriers are not fail-proof (Reason, 2000).

A predominant number of prevention controls on the left side of a Bow-tie is indicative of a proactive management strategy while a predominant number of mitigation and recovery controls on the right of the Bow-tie is indicative of a reactive management strategy. It is noted that proactive management strategies are typically considered the most cost effective approach to manage risks because reactive management strategy is only dealing with the consequences of an event that could not be prevented (Saud et al., 2014). The green tag of the prevention control indicates that this management strategy carries less uncertainty of achieving the objectives than the mitigation (Yellow) and recovery (Red) controls.

The lines between the cause, event and consequences represents the causal pathway of risk from the hazard to the losses (Reason, 2000). Similar to the acyclic structure of a Bayesian Belief Network, the Bow-tie does not have feedback loops because once the event has occurred and the consequences experienced, there are no prevention, mitigation or recovery controls that can return the situation to the state prior to the event (#02 Cormier et al., 2018; Badreddine and Amor, 2013; Khakzad et al., 2014). Once an accident has occurred and the damage done, the repairs will not return the damaged components to their original states. The repaired or replaced components can only recover the functions of the damaged components. After the fact, any improvements to the prevention controls to reduce the likelihood of a future event only affect future states - the consequences have already occurred (Kjølle et al., 2012). A cascade of events and consequences across several Bow-tie is a valuable model to understand the pathways of cumulative risks across several management systems (Swuste et al., 2019). It is particularly useful in identifying what are the root causes of risk and which management system of prevention, mitigation and recovery controls are better positioned to manage them. However, it is also useful to identify risks that cannot be prevented such as natural disasters pointing the need for effective mitigation and recovery controls (Chakraborty et al., 2018).

In Figure 9, the Bow-tie structure of Figure 7 is bridged to a marine ecosystem-based management context. Following the same analogy, the source of the risks are marine activities and their demands on ecosystem services. The causes are the pressures generated from these activities that can alter abiotic ecosystem components that can subsequently have effects on the biotic life-cycle functions they support, as the consequences. Based on the discussion in Section 3.1, the environmental protection regulatory frameworks represent the prevention controls that are in place to reduce the likelihood of altering abiotic ecosystem components while the marine protected areas and restoration activities are the mitigation and recovery controls to address the consequences if the event occurs.

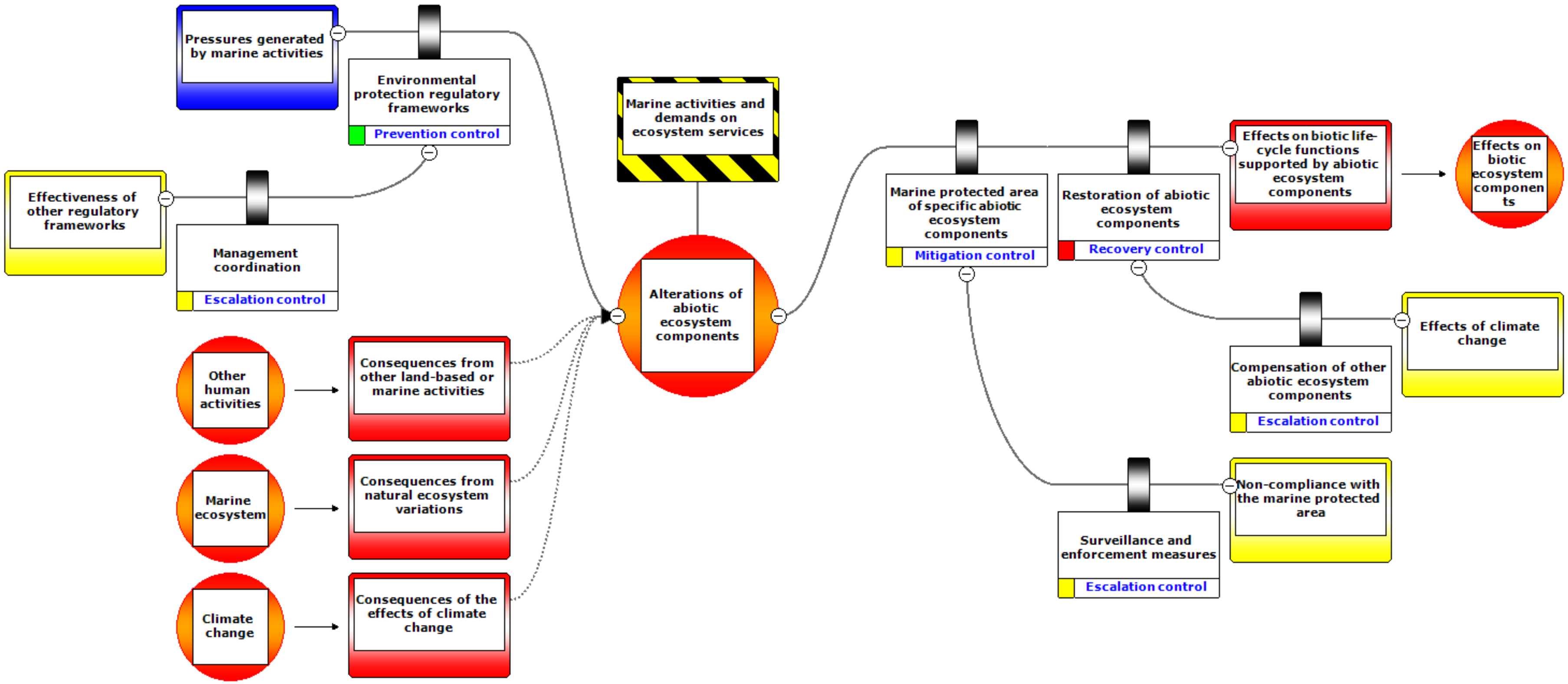


Figure 9. Bow-tie analysis of a marine ecosystem-based management context.

Given that the environmental protection regulatory frameworks can never be fail-proof (e.g. eliminating any residual pressures on the ecosystem components), marine protected areas and restoration measures are, for example, the mitigation and recovery controls implemented as a conservation strategy. As examples of escalation factors for a prevention control, the effectiveness of other regulatory frameworks that could undermine the effectiveness of the environmental protection regulatory frameworks would be addressed by management coordination between jurisdictions. As for escalation factors that could undermine mitigation and recovery controls, a lack of compliance for marine protected areas would be addressed by increased surveillance and enforcement activities while the effects of climate change on restoration activities would be addressed by additional compensation activities. This example also shows that the consequences of cascading events from other land-based and marine activities, natural ecosystem variations and the effects of climate change can directly alter the abiotic ecosystem components and, thus, bypass the environmental protection regulatory frameworks rendering them ineffective. This would leave marine protected areas and restoration activities to deal with the effects to the biotic life-cycle functions as a result of altered ecosystem components. Finally, the effects to the biotic life-cycle functions that could not be mitigated or recovered would subsequently become a cascading consequence that would directly have an effect on the biotic ecosystem component and biological diversity.

The environmental protection regulatory frameworks represents the proactive management strategy while the marine protected areas and restoration activities represent a reactive management strategy or, rather, the marine conservation strategy. Although this could be argued as a simplistic conceptual diagram, it does provide food for thought as to the important role that environmental protection regulatory frameworks plays in ecosystem-based managed strategies. As a reactive management strategy, it also tells us that ineffective environmental protection regulatory frameworks combined with the effects from other human activities, natural ecosystem variation and the effects of climate change could render the marine conservation strategies efforts in vain leading to a cascade of biological diversity effects. In Bow-tie analysis, the occurrence of an event is an indication of a loss of control or, rather, an indication of ineffective prevention controls. It also tells us that lack of proactive management strategies (e.g. prevention controls) would ultimately render mitigation and recovery controls useless as the frequencies of the events and the magnitude of the consequences continue to escalate. In an ecosystem-based management strategy, marine conservation strategies could ultimately be in vain if environmental protection regulatory frameworks are not effective combined with the effects caused by the consequences of the cascading events mentioned above. In this context, horizontal integration of the environmental protection regulatory frameworks and marine conservation strategies are needed because protection and conservation outcomes can only be achieved as a result of the combined effectiveness of the two management regimes. Finally, the use of cascading events in a cumulative risk context is also a valuable approach to develop a cumulative effects assessment framework.

Even though it is primarily a qualitative assessment technique, the Bow-tie analysis is a valuable approach to structure the management problem and understand where potential vulnerabilities would need additional management attention. As discussed in Chapter 3, the Bow-tie can help identify the regulators and stakeholders that would need to be consulted as well as help formulate the questions to be answered by science or formal scientific advisory processes (#04 Cormier et al., 2019).

From this point onwards, the Bow-tie diagram is used to walk through the risk management process steps.

4.2 Establishing the policy context and scope in marine planning and management

Chapter 3 outlined the importance of analysing the context of the legislation to establish the scope of the marine planning process. In risk management, the risk assessment is not started unless the context and scope has been established in consultation with regulators, stakeholders and scientists. This step of the risk management process is key to ensure transparency as to 'why' the process is being initiated given the mandate of the planner acting on behalf of competent authority. It also scopes the issues and concerns that will be assessed to ultimately identify the regulatory frameworks that may need improvements. *A priori*, the process does not start with a view that a given environmental protection regulatory framework is not working nor does it start with justifying the need for marine conservation measures until the risk assessment has been completed. As mentioned earlier, this first step in the process should dedicate a significant amount of the human and financial resources that was allocated for the planning process. The context and the scope is a key aspect for providing transparency as to what the process will do while addressing the expectations of those involved. Although ISO 31000 and IEC 31010 standards provide the necessary framework and tools to conduct a risk management process, the policy framework for what is going to be managed is also necessary. A risk management process cannot be initiated without the policy framework.

Figure 10 and Figure 11, is a Bow-tie analysis of the MSFD programme of measures and the Fish and Fish Habitat Protection Policy Statement (FFHPP) discussed in Chapter 3. These two diagrams establish the risk management context and scope of the two respective policy frameworks. The competent authorities that would lead the planning process of the MSFD or manage the regulatory authorization of the *Fisheries Act* are identified under the source of the risk (Yellow striped box). Given the broader range and marine activities to be managed by the MSFD, there would be different competent authorities that would be implementing the controls of the programme of measures. It would also require coordination, incentives and consultations as a means to address transboundary impacts as escalation factors that could undermine the effectiveness of the controls being implemented by a given jurisdiction.

The MSFD reflects a broader scope for planning than the regulatory process of FFHPP. The former is a planning directive for human activities and demands on natural ecosystem services while the latter is a regulatory framework to manage the impacts of a work, undertaking or activity on fish and fish habitat. Although both have sustainability as their long-term goals to be reached, their objectives are a reflection of their different in context. The objectives of the MSFD is to achieve and maintain good environmental status while the FFHPP is to manage direct or indirect impairment of fish habitat's capacity to support one or more life processes of fish. Given that this is a risk management framework in contrast to a risk assessment framework, both policies define the expected outcomes for the management measures to achieve their objectives. These expected outcomes are also in line with the Bow-tie definitions for prevention, mitigation and recovery controls. For the MSFD, input controls and spatial and temporal distribution controls (e.g. prevention controls) would be expected to reduce the likelihood of exceeding the output controls (event of concern) that would require mitigation and remediation tools (e.g. mitigation and recovery controls) to restore the damaged ecosystem components of the marine environment when the output control is exceeded. As for FFHPP, avoidance measures (e.g. prevention controls) are expected to prevent a harmful alteration, disruption or destruction of fish habitats (e.g. event of concern) and mitigate the spatial scale, duration, or intensity of harmful impacts to fish habitat when such impacts cannot be avoided (e.g. mitigation controls) or offset the residual impacts after efforts have been made to avoid and mitigate the harmful impacts to fish habitat (e.g. recovery controls).

Both diagrams are a representation of the context and scope for the planning and regulatory processes to be conducted within the mandate of the competent authority leading such a process. Here, the two very different frameworks are compared to demonstrate the different scope from a planning versus an environmental protection regulatory framework context. It helps stakeholders understand the different objectives of each legislative and policy frameworks. Biodiversity or pollution concerns are within the scope of the MSFD while concerns are scoped to fish habitat impacts under the scope of the FFHPP.

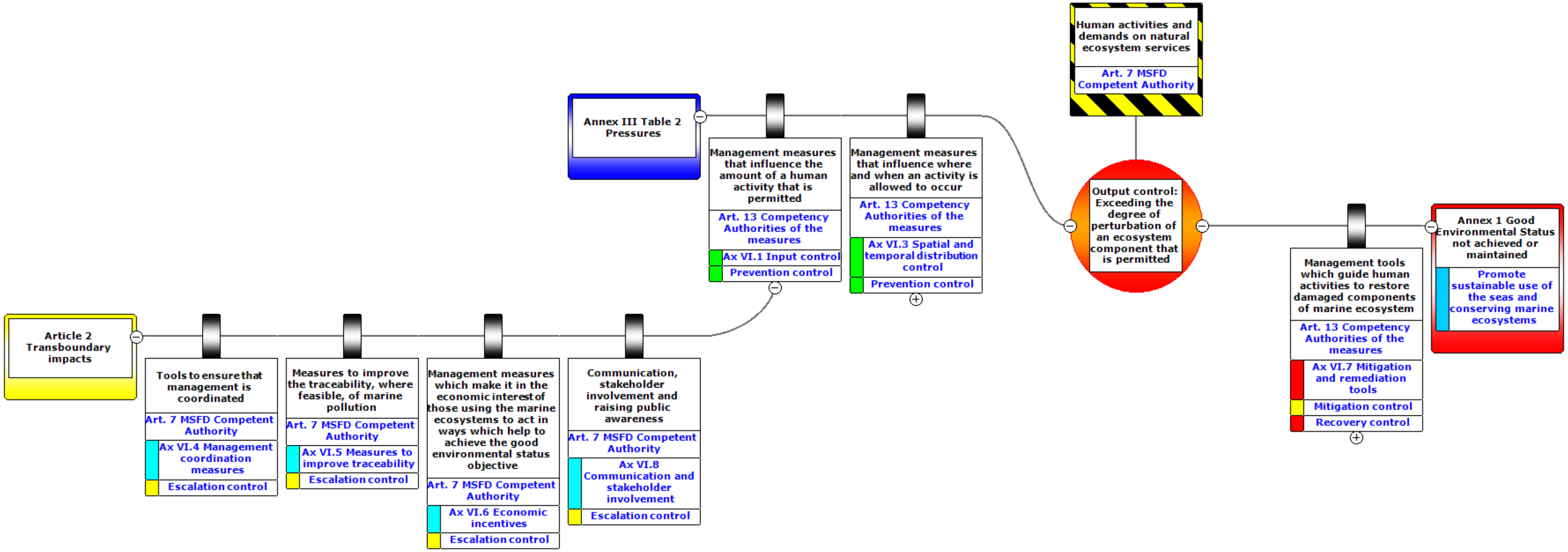


Figure 10. MSFD controls from the programme of measures (#08 Cormier et al., 2018).

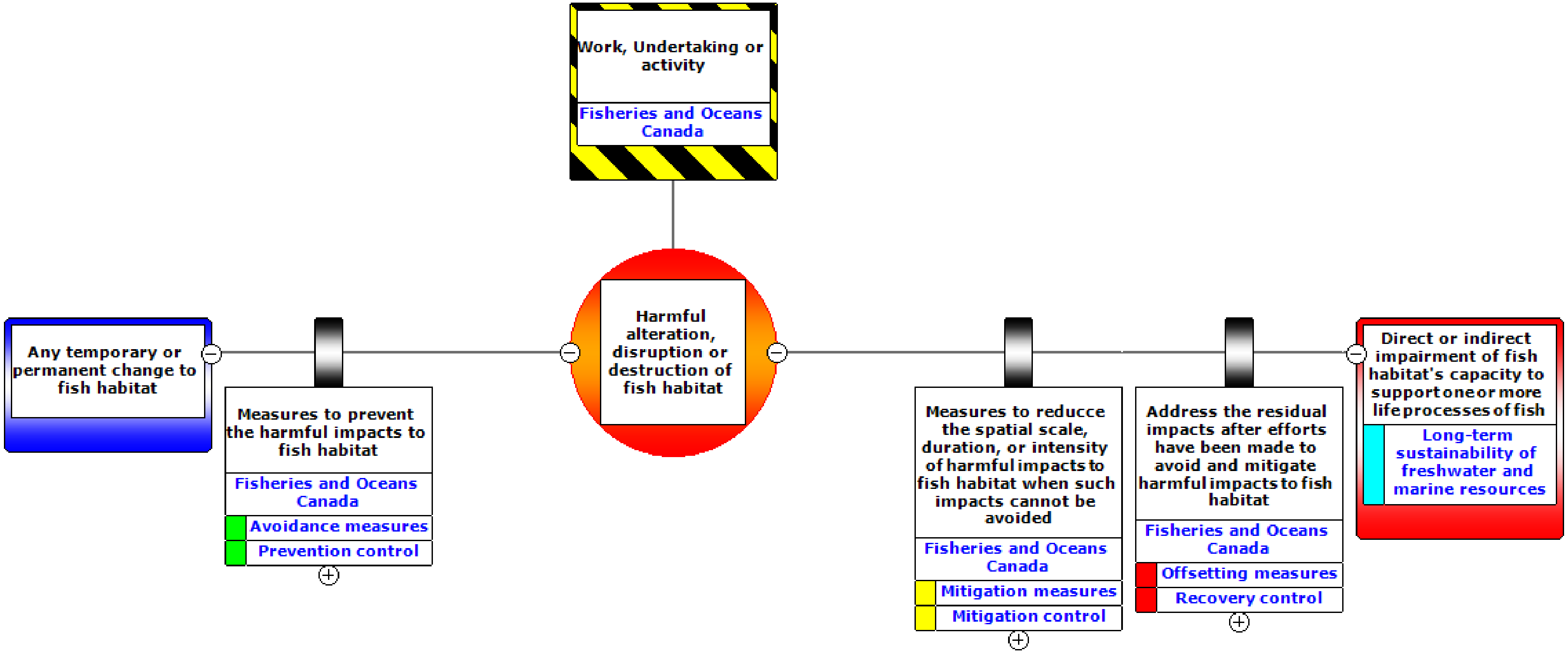


Figure 11. Bow-tie analysis of the fish and fish habitat policy (DFO, 2019a).

This analysis helps the stakeholders understand what can be managed and what cannot be managed given the authorities and mandates of the two frameworks. This also helps scientists understand the different science advice that would be needed for very different questions. In the case of the MSFD, it also helps the planner identify the regulators that should be part of the planning process given that their environmental protection regulatory framework will ultimately need to address MSFD concerns. For example, a planner would have to collaborate with the relevant regulators regarding the pressures to the integrity of the seafloor to address good environmental status. The planner could also analyse the avoidance measures to avoid harmful impacts to fish habitats, using FFHPP as an example, to determine if they are equivalent to the expected outcomes of the input controls and the spatial and temporal distribution controls of the programme of measures of the MSFD.

This demonstrates the importance of establishing the context and the scope in any marine planning initiatives before starting an assessment. In risk management this step is key to assist the planner in conveying 'why' the process is being initiated, 'what' are the concerns to be addressed and 'how' these concerns are to be addressed given the current regulatory frameworks. It helps the planner respond to the concerns and expectations that are rightfully raised by stakeholders and frame the questions for scientific advice.

Given the planning focus of this thesis, the MSFD is used to describe how the risk management process of ISO 31000 is used to identify, analyse, evaluate, treat and monitor risks during the planning process based on the context and scope established above (Figure 6).

4.3 Identifying the sources, causes and consequences of risk

Having established the context and scope for the risk management process, risk identification is then initiated to identify the sources of risk that could undermine management efforts in achieving the policy objectives as well as the mechanisms that could cause an event of concern and the consequences of such an event. In an ecosystem context, risk identification is where the scientific efforts come into play.

In Section 4.2, the legislation and policies are used to establish the risk management context and scope of the risks to be assessed and subsequently managed. In risk identification, further analysis of the policies can add the necessary level of detail to characterise the mechanisms that could cause an event of concern, the event itself and the consequences of such an event. Working with the Bow-tie for Descriptor 6 Seafloor integrity of the MSFD (Figure 12), smothering, sealing, changes in siltation, abrasion and selective extraction of seabed and subsoil could eventually change the integrity of the seafloor to a point that adversely affect its function and benthic ecosystems. The input controls and spatial and temporal distribution controls of the human activities should be implemented to reduce these pressures to safeguard the integrity of the seafloor. Using the structure of the Bow-tie of Figure 12, these controls should reduce these pressures to a level that do not exceed the degree of perturbation of the ecosystem components of the seafloor that could adversely affect it. In other words, the prevention controls should not exceed the output control. Now comes the paradoxical questions of defining the ecosystem component and the threshold that could characterize the degree of perturbation that would be acceptable to maintain the seafloor structures, functions and benthic ecosystems (Gregr et al., 2013). Although the MSFD set the boundaries for the assessment within a regional sea context, the ecosystem component and their functions would still needs to be identified (Gregr and Chan, 2011).

In addition to the risk criteria that is discussed in Section 4.5, there is also a need for additional criteria to characterize the risks resulting from the causes, events and consequences that are of concern to the policy objectives. The criteria are most important to identify the inherent vulnerabilities to risk and the magnitude of the consequences of such risk.

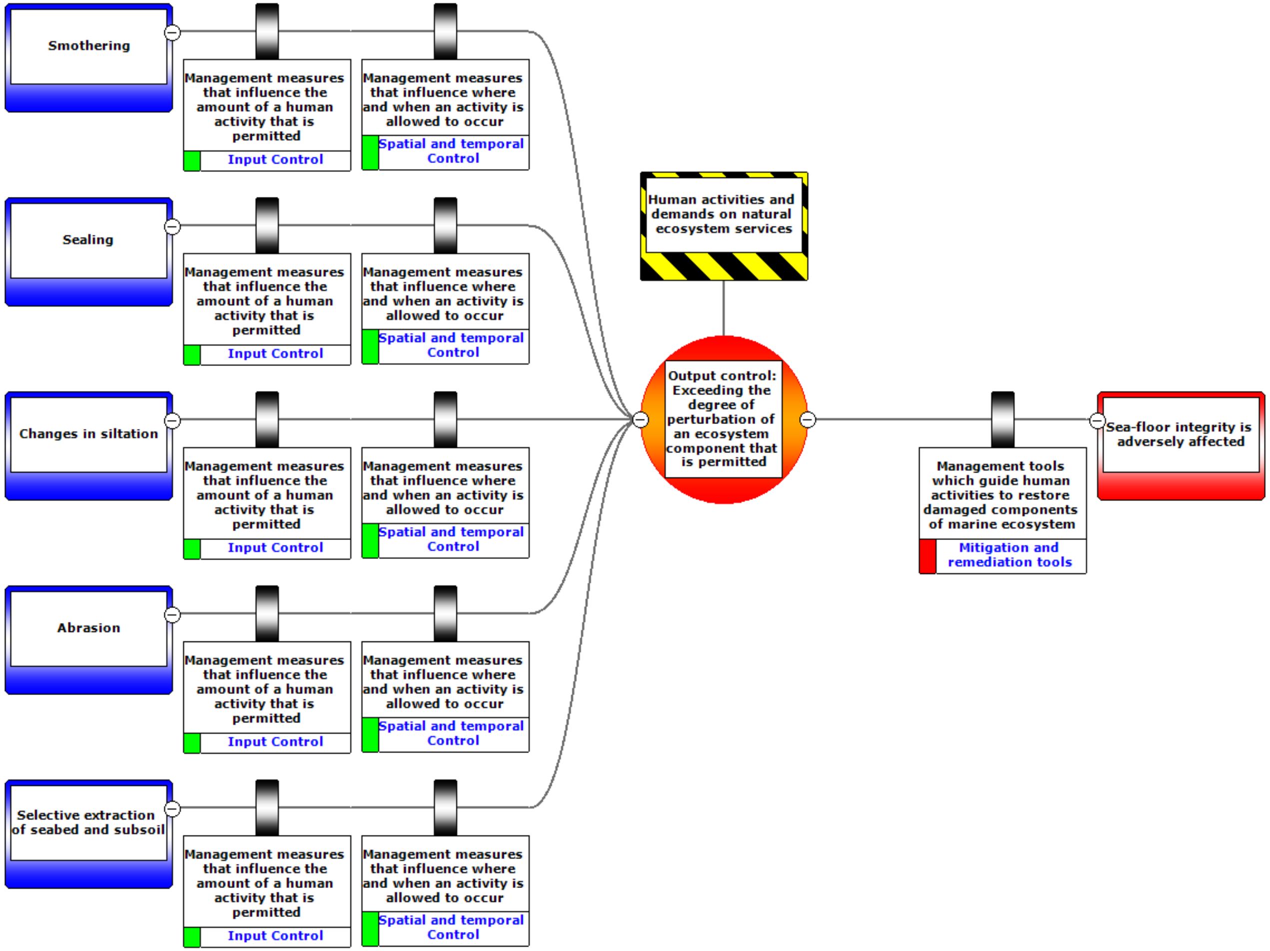


Figure 12. Bowtie analysis for seafloor integrity Descriptor 6 of the MSFD (#08 Cormier et al., 2018).

The MSFD is recognized as a very comprehensive strategic framework to develop an ecosystem-based risk management approach to human activities for any environmental protection regulatory framework (#14 Cormier, 2019; UNECE, 2018). However, it lacks the normative framework to characterize the significance of the functions supported by the ecosystem components in a given ecosystem boundary and the significance of the consequences that could occur due to the pressures generated by human activities (#05 Cormier and Lonsdale, 2019).

In environmental impact assessments and marine planning, valued ecosystem components (VEC) are typically used as criteria to prioritize risks and vulnerabilities (Olagunju and Gunn, 2013, 2016). However, VEC's can lead to debates of values between the scientists that value biodiversity for conservation and stakeholders that value the resources they depend on (Dunstan et al., 2016). Vulnerable marine ecosystems (VME) is another classification scheme that was developed in the context of fisheries impacts on ecosystems (Watling and Auster, 2017). There is a multitude of classification schemes to characterise values, vulnerabilities, importance, etc. (Dunn et al., 2014). However, VECs and VMEs do not necessarily provide the criteria to identify the significance of the functions provided by an ecosystem component that could be perturbed by pressures generated by human activities (Piet et al., 2017). For example, a targeted species that is a valued fisheries resource still relies on ecosystem components that provide vital lifecycle functions such as spawning, breeding, feeding, migration or refuge to that species (Gregr et al., 2012). Alterations or destruction of such components would ultimately have an effect on the dependent species populations (Borgwardt et al., 2019). Therefore, the significance of a life-cycle function provided by an ecosystem component is a vital ecological consideration in managing the pressures (#05 Cormier and Lonsdale, 2019; #13 Cormier et al., 2016; Gregr et al., 2012).

Although the concepts for ecologically and biologically significant areas have evolved considerably from its original development (Gregr et al., 2012), the original Canadian version of the criteria for ecologically and biologically significant areas (EBSA) and species (ESS) (DFO, 2004, 2006) were intended to classify the significance of the functions supported by ecosystem components in a given bioregional context (DFO, 2009d). These criteria were originally developed to call attention to areas and species that have particularly high ecological and biological significance needing a '*greater-than-usual*' degree of risk aversion in the management of human activities. The definition of '*significance*' refers to areas or species that if perturbed severely would result in ecological consequences greater than an equal perturbation of most other areas or species. Of course, the nature of the consequence would reflect the habitat features and species diversity of the said ecosystem located within that particular bioregion. More importantly, significance is not considered in terms of the value or importance of a habitat feature, species or area that has special utility to humans such as fisheries resource, charismatic species, or habitat features valued for conservation reasons by the public, governments, administrations, stakeholders or even scientists. From a risk management perspective, a component that provides significant ecosystem functions are the vital components or, in other words, are the Achilles heel of the ecosystem and would require a greater-than-usual degree of risk aversion from an ecosystem-based management approach.

Extracted from (DFO, 2004), Table 3 shows that a spawning and breeding area would be considered as highly significant if it is the only suitable spawning ecosystem component known for a given species compared to spawning and breeding components that are widespread throughout a bioregion. Such criteria can identify the relative ecological and biological significance of areas and species to identify the significance of the consequences of losing such component. In this context, risk aversion implies that the ecosystem components that are providing significant functions would be assessed in terms of their vulnerability to the perturbations of relevant pressures generated by human activities such as seafloor integrity for example (Figure 12) The likelihood of a component losing its functions would therefore depend on the spatial extent, dispersal, frequency, and persistence of the pressures on this component (Borgwardt et al., 2019). In contrast, the criteria for ecologically significant species (ESS) are used to characterise the ecosystem function that a species provides such as key trophic species, highly influential predators, nutrient importing/exporting species, structure providing species, and properties at the community level (DFO, 2006).

Table 3. Example of the criteria to evaluate the significance of the ecosystem function of an ecosystem component (DFO, 2004).

		Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Spawning / Breeding	High	Only one suitable spawning site known to exist for a species; Site used for spawning by many species	High percentage of total population use the area; Noteworthy percentage of many species use the area	Semelparous, so loss of one spawning event poses risk of loss of lineage; or a single site's quality or quantity of breeding habitat greatly affects the productivity of the population.		
	Low	Suitable spawning sites are widespread over a large number of at least partially disjunct areas	Only a small portion of the population(s) is present at any given time.	Continuous reproduction throughout the year, over many years. Reproduction occurs at many sites. A single site's quality or quantity of breeding habitat has little effect on the productivity of the population		
Nursery / Rearing	High	Only a single nursery/ rearing area exists for the species	Larvae/juveniles are found in high concentrations in an area or a number of species use the area as nursery grounds/rearing	Larvae/juveniles have increased survivorship/fitness compared to other areas, especially if for reasons which can be tied to characteristics of the site.		
	Low	Multiple nursery/rearing sites for the species	Larvae/juveniles widespread or found evenly over a large area or single species uses area for nursery/rearing purposes	Larvae/juveniles fitness is comparable to adjacent habitats		

In an MSFD context, the criteria for ecological and biological significant areas and species could help identify the significant functions of the ecosystem components to characterize the output control. However, the challenge would still lie in establishing the "degree of perturbation of an ecosystem component permitted" given the uncertainties involved in setting such thresholds.

As an example of such an approach, the criteria for ecologically significant species was used to identify the ecosystem component that is vulnerable to nutrient loading and eutrophication in estuaries in the Southern Gulf of St Lawrence in Canada (Bugden et al., 2014; Coffin et al., 2018). After several years of management responses to anoxic events in these estuaries, scientific efforts shifted from monitoring these events to characterizing the relative land-based sources of nitrogen (Grizard, 2013). Given the need to identify the significance of the functions of the ecosystem components affected by nutrient loading, a scientific advisory process established eelgrass (*Zostera marina*) as an ecologically significant species because it is a structure providing species that support multiple species life-cycles and habitat functions(DFO, 2009a).

Given the need to reduce the pressures of nutrient loading to ultimately reduce the vulnerabilities of eelgrass, a subsequent advisory process was organized to identify the stressors that could result in a harmful alteration, disruption or destruction of eel grass beds using the *Fisheries* Act fish habitat policies at that time (Table 4) (DFO, 2012a).

Table 4. Possible thresholds for no effects, disruption, harmful alteration and destruction of eelgrass (DFO, 2012a).

Stressor	Indicator	No effect	Disruption	Harmful Alteration	Destruction	Comment
Sedimentation	Depth	ND	ND	ND	> 5 cm deposition	single event (< 2 months duration)
	Depth	ND	ND	ND	> 8 cm per year	Burial of rhizomes
	Depth	< 0.1 cm per year	ND	ND	> 0.5 cm per year	Long term
Turbidity	Total suspended solids	< 20 mg L^{-1}	ND	ND	ND	Depth dependent
	Surface light	> 60%	ND	ND	< 35%	Depth dependent
	Darkness	ND	ND	ND	> = 3 days	
Nutrients	Water column concentration	ND	ND	ND	Toxicity at > = 3 µM NO_3 – N day^{-1}	
	Water column concentration	ND	toxicity from ≥100 µM NH_4^+	ND	ND	
	Thickness of benthic algae	ND	≥5 to <10 cm	≥10 cm	≥25 cm	
	Loading rates per estuary surface area	≤12 kg N per ha per year	ND	>30 kg N per ha per year	≥60 kg N per ha per year	screening guide only, variable thresholds
	Anoxia	< 8 hours	< 12 hours	18 to 24 hours	≥36 hours	At 20ºC
Water flow	Current	ND	< 16 cm s^{-1}	ND	>120 to 180 cm s^{-1}	
	Current	ND	>25 cm s^{-1}	ND	ND	continuous cover of bed disrupted
	Erosion	ND	< 25% of shoot rhizomes exposed	ND	ND	
	Erosion depth	ND	≤6.5 cm	>6.5cm	≥15cm	

Using the Bow-tie structure for Descriptor 5 for human-induced eutrophication of the MSFD (Figure 13), the expected outcome of the input control and spatial and temporal distribution controls were used to conduct an extensive analysis of land-based legislation, standards and guidelines in collaboration with the jurisdictions involved. Eel grass as an ecologically significant species provided the ecosystem component for the output control and the subsequent advisory process for the stressors characterized the degrees of perturbation (e.g. harmful alteration, disruption and destruction).

Although the MSFD is a European directive, the Bow-tie analysis was used to structure the risk management problem and organize the scientific information to show that the eutrophication status of the estuaries was not good based on the frequencies of anoxic events. Using the ecologically and biologically significant areas and species criteria helped identify the vulnerable ecosystem component for the output controls and scope the degree of perturbation for the stressors of this ecosystem component. The expected outcomes of the MSFD controls (Left side of the Bow-tie) were used to structure the analysis of the legislation, standards, and guidelines used to manage land-based activities. Even though everyone involved was preoccupied with the inputs of fertilizer, the MSFD Bow-tie for Descriptor 5 played a normative role of ensuring that the inputs of fertilizer and organic matter were equivocally considered throughout the process and, thus, avoiding anchoring on the fertilizer as the only source of the problem. The Bow-tie analysis structured the management problem that also structured the ecosystem-based considerations for management. From a normative perspective, the Bow-tie structure helped managers, stakeholders and scientists understand the pathways of risk and the vulnerabilities of the ecosystem component (e.g. eel grass and stressors) to devote their efforts to the analysis and evaluation of the management measures. Research is currently being conducted on eel grass and eutrophication to find management and monitoring solutions to the current eutrophication events (Coffin et al., 2018; Schein et al., 2011).

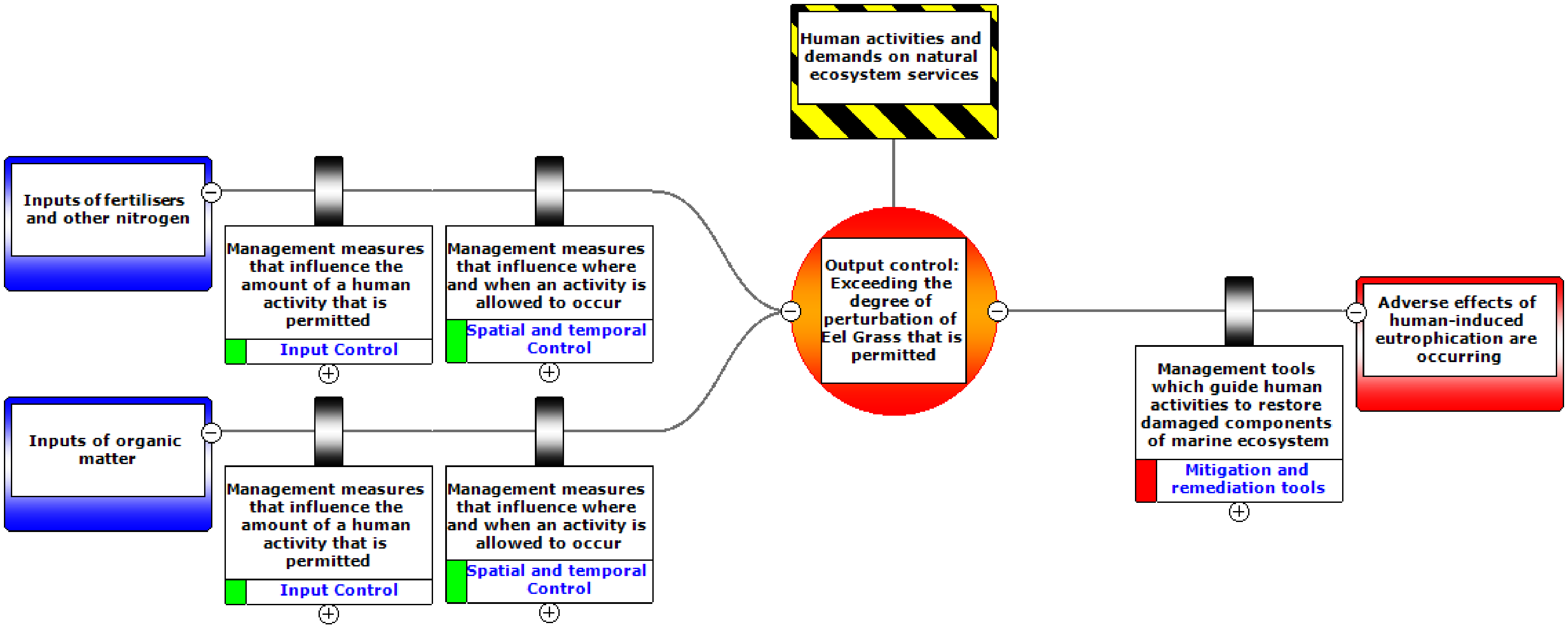


Figure 13. Bow-tie analysis of the MSFD Descriptor 5 for eutrophication adapted for eel grass (Zostera marina) (#08 Cormier et al., 2018).

Although the Bow-tie is often dismissed as being a qualitative tool, this example demonstrates the value of structuring the management problem to help identify the risks that need to be managed or, rather, to identify the risks to be managed given the policy objectives to be achieved. Once the management problem is understood by all, we are better able to formulate the questions to science and the research that needs to be done. It also provided the structure to identify and analyse the relevant environmental protection measures that are used to reduce the pressures from very specific human activities.

In Canada, ecologically and biologically significant areas have been identified for a large part of the Canadian exclusive economic zone (DFO, 2018, 2015b, 2014c, 2013a, 2011c, 2007b). Although the identification of these areas tend to be used for conservation strategies, these criteria can help identify the suite of pressures that such components are vulnerable to and, subsequently, identify the relevant regulatory frameworks that manage the relevant human activities and their pressures that may need improvements. However, these criteria lack the strategic aspect of the MSFD that provides definitions for the pressures, controls and descriptors to develop an ecosystem-based risk management approach using these ISO and IEC standards.

Without a clear understanding of the sources of the risk, the causes of an event and the consequences of such an event, we are driven to ever improving the assessment of the consequences to reduce scientific uncertainties. Identifying the risks of not achieving policy objectives shifts our attention to the root causes of the events of concern and the management measures that would need to be analysed to determine how best to manage the root causes to achieve those objectives. It does not undermine the scientific efforts to reduce scientific uncertainties and improve knowledge. The lessons learned from the eutrophication example is the importance of structuring the management problem linking the ecosystem outcome characterized by the output control for eel grass to the nutrient loading pressures in order to identify the measures that may need improvements. This is where the Bow-tie analysis proves to be a valuable tool to structure the MSFD into a risk management framework incorporating ecological and biological criteria to characterize the output control.

4.4 Analysing the consequences of current and potential management scenarios

Risk analysis involves a qualitative or quantitative analysis of the likelihood of an event of concern and the nature and magnitude of the consequences of such an event that were identified in risk identification. This is very much what we traditionally do in ecosystem-based science and ecosystem risk assessments (Halpern et al., 2008; Hobday et al., 2011). However, it also requires the analysis of the effectiveness of existing prevention, mitigation and recovery controls as discussed in earlier examples (Figure 12 and Figure 13). In risk evaluation, the planner in consultation with regulators and stakeholders evaluate the effectiveness of the management scenario given the objectives that are being sought. Therefore, the analysis of the effectiveness of the prevention controls are expressed in terms of their capacity to reduce likelihood of the event of concern and the mitigation and recovery controls in terms of their capacity to reduce the magnitude of the consequences of such an event.

Based on the Bow-tie structure of the MSFD, exceeding the output control is the event that can lead to a descriptor of good environmental status not being achieved (#05 Cormier and Lonsdale, 2019; #08 Cormier et al., 2018; #13 Cormier et al., 2016). The Bow-tie also tells us that the input controls and the spatial and temporal distribution controls manage the activities and their pressures to avoid exceeding the output control. Therefore, the effectiveness of these controls is in reducing the initial pressure to a level that does not exceed the degree of perturbation of the ecosystem component as the output control (#02 Cormier et al., 2018). Thus, the residual pressure is technically an indicator of the effectiveness of the controls while the output control characterizes the event that could occur. However, the output controls does not explicitly convey the risk implications if it is exceeded with exception of being linked to the descriptor that could be affected.

Understanding that productivity-state changes relationships of likely responses of fisheries productivity to various fish habitat changes are not linear (DFO, 2013b), a conceptual framework was developed to structure the assessment of the impacts from pressures generated by human activities on an ecosystem component and its function (DFO, 2015a). This particular science advisory process was initiated to establish ecosystem-based risk criteria to be used in marine planning. Conceptually, Figure 14 shows that increasing pressures on a given ecosystem component will ultimately lead to a loss of function that is supported by the component.

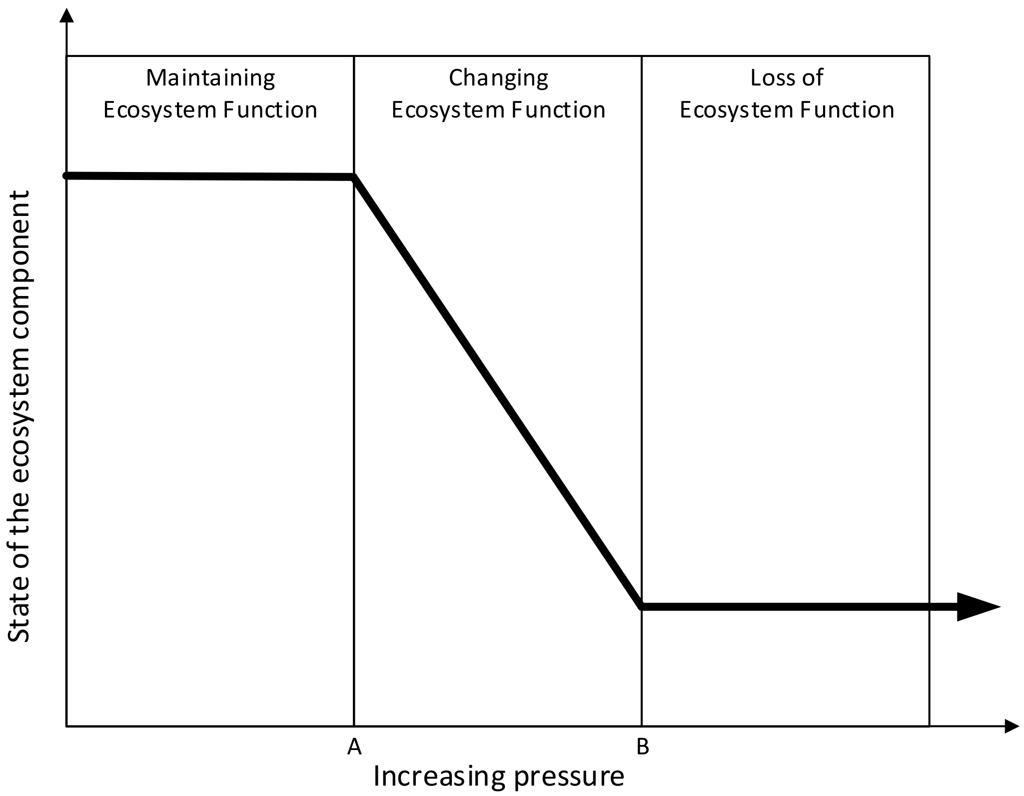


Figure 14. The relationship between the effects to the function of ecological components as a result of increasing pressures (DFO, 2015a).

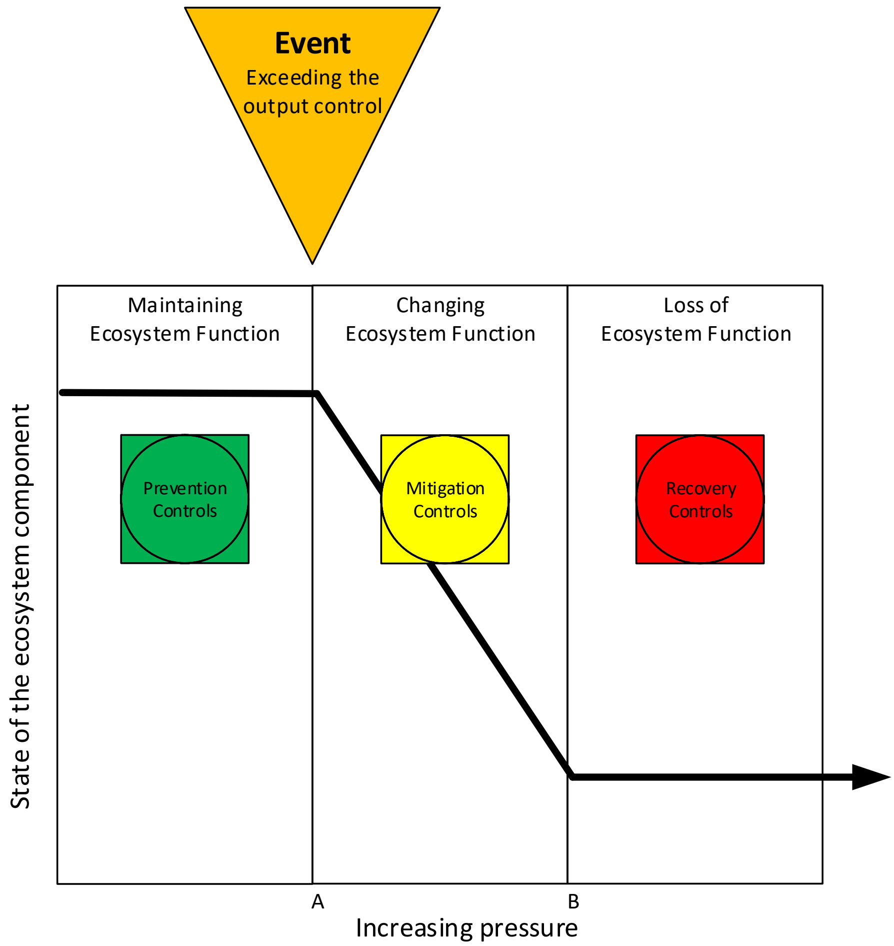
As the pressure increases, the component reaches a transition point A where it can no longer maintain the functions it provides. From that moment onward, the function of the ecosystem component continues to change with increasing pressures until the component reaches a final transition point B where the function is lost (Table 5).

Table 5. Categories of changes to ecosystem functions as pressures on ecosystem components increases (DFO, 2015a).

Maintaining Ecosystem Function	Transition point between maintaining and changing functions	Changing Ecosystem Function	Transition point between changing and loss of function	Loss of Ecosystem Function
a) Ecosystem function is maintained although there may be changes in the status of the ecosystem component. b) The ecosystem component resists or rapidly compensates in the face of perturbation so that it can be inferred that the ecosystem function its supports is maintained.	The ecosystem's ability to fully resist or fully compensate for lower values in the ecosystem has been exceeded. Further degradation of the ecosystem component will reduce its capability to contribute to the ecosystem function	a) Ecosystem function systematically changes as the ecosystem component changes in the face of perturbation. b) The ecosystem component changes with the perturbation, and is in states where decreases in function are generally likely to occur. Recovery of the ecosystem component is expected to be secure, but a period of altered status of the component is expected.	The ecosystem component has lost its ability to recover. The status of the ecosystem component may not yet have been reduced to a point where it no longer contributes to the ecosystem function, but because the component has lost its ability to recover it is expected that the contribution of the component to the function will continue to decline until such a point is reached. In rare cases the function is so dependent on the specific ecosystem component that it may be reduced beyond acceptable level of impact, before the component has lost its ability to recover. Such situations can only be document in very information risk systems.	a) Ecosystem function can no longer be supported by the ecosystem component. b) The ecosystem component has reached a status where evidence indicates that the function can no longer be provided; or the ecosystem component has been degraded to a status where recovery is no longer secure; even if the pressure is removed from the loss of the function will continue to accumulate.

In Table 5, “item a)” in each of the three columns describes the conceptual relationship between the pressures, the ecosystem component and the dependent function it offers. “Item b)”, however, describes the repercussions of each state that is of most concern in a risk management policy context. At the onset of the pressure, the ecosystem component can resist or compensate the resulting perturbations and the functions it supports is maintained. From a risk management perspective, this implies that the actual pressure or the residual pressure of current management measures are not high enough to affect the function of the ecosystem component. Management would expect to achieve the objectives. However, once the pressure exceed the transition point A, the function is likely going to decease as the ecosystem component changes from the increasing perturbations. Although the ecosystem component is expected to recover if the pressure is reduced or eliminated, there is uncertainty that the objectives would be achieved without improving the effectiveness of the management measures to further reduce the pressures. However, objectives are certainly not achieved after the transition point B when the ecosystem component reaches a state where the function is lost and that recovery is no longer secured even if the pressure is removed. This would be an indication of an ineffective management strategy or a loss of control as stipulated by the Bow-tie analysis.

In a Bow-tie context, this implies that the prevention controls should manage the human activities and their pressures to reduce the likelihood of exceeding the transition point A (Figure 15). Once exceeded, mitigation controls would be needed to reduce the spatial scale, duration or intensity of the pressures to allow the ecosystem component to recover and maintain its function. Finally, recovery controls would be the only options left once the ecosystem component has exceeded transition point B and has lost its function. In an MSFD context, this would imply that the input controls and the spatial and temporal spatial controls should manage human activities to reduce the residual pressures to levels that should not exceed the output control to maintain the function of the ecosystem component of concern (e.g. transition point A). This leaves the mitigation and remediation tools of the programme of measure to reduce the spatial scale, duration or intensity of the damage to restore the ecosystem components in the marine environment.



Prevention Controls	Mitigation Controls	Recovery Controls
Input controls Spatial and temporal distribution controls	Mitigation tools	Remediation tools

Figure 15. The role of the controls in the reduction of pressures to ecosystem components and magnitude of the effects to ecosystem functions.

Figure 15 shows that combining the criteria of Table 5 with the expected outcomes of the controls of the MSFD provide valuable insight as to the type of indicators that could be developed to assess the effectiveness of those management measures. The indicator for the effectiveness of the input controls and the spatial and temporal controls would be framed by the collective residual pressure against the output control as the benchmark of effectiveness. However, this approach also shows that the indicators for the effectiveness of the mitigation and remediation tools would be a measurement of the spatial scale, duration or intensity of the restoration done to the ecosystem component. The challenge would then be to link these indicators in a causal relationship to the indicators of a good environmental status which is already proving to be a daunting task (Berg et al., 2015; Borja et al., 2013; Korpinen and Andersen, 2016; Rice et al., 2012).

The output of the risk analysis process is primarily a statement regarding the effectiveness of current management measures against risk criteria that reflect the causal concerns of not achieving a given objective. The repercussions to ecosystem functions outlined in Table 5 can be used to develop a risk criteria of the causal range of consequences reflecting ecological repercussions of managed or unmanaged pressures. The effectiveness of current management scenarios would be compared with proposed improvements in terms of the likelihood of exceeding the output control and the consequence of that event in risk evaluation.

4.5 Evaluating the management scenarios for implementation

Risk evaluation is the decision point that closes the risk assessment process. It is where the scientific and technical experts hand over the results of the risk analysis to managers, regulators, and stakeholders to evaluate the management scenarios and inform a decision as to how best to reduce the uncertainties to achieve the objectives at hand. The evaluation is done by comparing the severity of the outcomes of the management scenarios in terms of the policy repercussions.

In risk management, risk criteria play as important a role as the legislation and policies used to set the context and scope of the risk management process. Risk criteria does not define which risk is acceptable or not (Baybutt, 2014b). Such criteria establish the level of tolerance to risk expressed as the repercussions of not achieving a policy objective (Rozmus et al., 2014). Given that risk can never be zero as long as activities that generate risk are pursued (Baybutt, 2014c), a management scenario that reduces the likelihood of an event or the magnitude of the consequence of such event or both is considered to reduce the effect of uncertainty on achieving an objective. As a risk policy, the risk criteria simply establish the likelihood and consequence combinations that are tolerable or not given the policy objective to be achieved. In cases where there are several policy objectives such as environmental, cultural, social and economic objectives in marine planning, a risk criteria and a risk matrix is needed for each individual policy as these may have different tolerance levels in decision-making.

The risk matrix is one of the most common graphical tools used in risk evaluation (IEC, 2019). A risk matrix should never integrate different policy repercussions into a single a risk matrix. As mentioned above, this is particularly important when considering multiple policy repercussions and consequences in marine planning or regulatory processes (#05 Cormier and Lonsdale, 2019; #12 Cormier et al., 2015; #13 Cormier et al., 2016). The repercussions to each objective needs to be considered separately in decision-making given the different values involved (Baybutt, 2014b; Cox, 2008). However, this implies that there is a need to integrate parallel risk assessment processes for each objective within the context and scope that was established at the beginning of the planning initiative (#06 Cormier and Kannen, 2019; #12 Cormier et al., 2015).

Qualitative risk matrices and their criteria should explicitly describe the risks and avoid ambiguous qualifiers (Cox et al., 2005). The risk criteria must explicitly describe the severity gradient of the same consequences typology (e.g. ecosystem consequences). The colour scheme of the matrices must also explicitly describe why a risk is considered tolerable or intolerable in terms of the policy objectives being sought (Baybutt, 2018). The use of simple qualifiers such as high, medium, low or 1, 2, 3 should be avoided as these do not convey a proper narrative of the risks to non-technical people such as managers, stakeholders or even the scientists (#05 Cormier and Lonsdale, 2019). Finally, a risk matrix does not make decisions. It is designed to inform decisions regarding the policy repercussions of not achieving policy objectives under different management scenarios.

In risk identification and risk analysis, risk is discussed in terms of the sources of the risk, the causes of an event, the likelihood of such an event and the magnitude of the consequences of such an event. Qualifiers of severity such as serious, harmful, destruction or impacts are not used in risk identification and risk analysis because these qualifiers are in the policy realm and not the scientific or technical realm. As mentioned earlier, scientific advisory processes should be independent and impartial of values. This is the reason why the risk analysis matrix does not have any colours compared to the same matrix for risk evaluation where the colours reflect the tolerance levels in terms of the policy objectives being sought. Given the complexity of leading multiple assessments across several disciplines and the uncertainties in the knowledge to assess each concern, such risk matrices are usually completed through expert solicitation processes for each of the disciplines involved in risk analysis. That does not imply that the risk analysis was not based on quantitative methods.

Figure 16, Figure 17, and Figure 18 are examples of three risks matrices showing the results of a risk analysis for two fictitious management scenarios. The risk matrix for ecosystem consequences uses Table 5 for the range of ecosystem consequences. The cultural risk matrix uses culturally significant criteria and repercussions (#16 Gee et al., 2017). The economic risk matrix is based on management policy frameworks (DFO, 2014b). This example shows the potential impacts (e.g. likelihood and consequences) and policy repercussions to environmental, cultural, and economic objectives regarding the management scenarios being considered. The text in the coloured boxes to the right describe the tolerance levels of the policy repercussions (Red, Orange, Yellow and Green). The dots on the risk matrices show the inherent risk (I_R) of the current management scenario in contrast to the residual risk (R_R) of the improved management scenario. In risk evaluation, managers, regulators, and stakeholders compare the inherent risk of a current management scenario with the residual risk of a proposed management scenario to evaluate their options.

In this fictitious example:

- The risk matrix for ecosystem consequences tells us that the effectiveness of the current management scenario is likely to cause a permanent loss of ecosystem function which is not tolerable given the ecosystem objectives being sought. However, the proposed management scenario would still require caution because it would possibly leave the ecosystem function vulnerable to changes. Given that the proposed management scenario may not be adequate given the uncertainties involved, additional monitoring would be needed to confirm the effectiveness of this approach.
- The risk matrix for the cultural consequences tells us that the concerns resulting from the current management scenario was addressed at the time this scenario was implemented. Since, collaboration with the community has maintained active participation in marine planning. However, the proposed management scenario would exacerbate these collaboration efforts given the potential effects

this would have on their cultural integrity. This would result in a long-term loss of trust and willingness to participate in marine planning.

- The risk matrix for economic consequences tells us that the current management scenario rarely causes issues to individual operators in this resource sector. The proposed management scenario would likely have an effect on market access for this resource sector. Discussions with the sector would be needed to identify which markets could be affected to find ways to mitigate the effects.

In summary, the proposed management scenario does reduce the uncertainties of achieving ecosystem objectives with additional precautions. Given that the local communities and the resource sector are used to the current management scenario when they were put in place a decade ago. There would be a need for consultation and engagement to identify the issues with the proposed management scenario.

This fictitious risk evaluation demonstrates the usefulness of the criteria to build a narrative to inform a decision-making process by those involved in the process that may not have the technical background. Is also demonstrates the challenge of writing such text without reflecting preferences or values. There will never be a perfect narrative given the subtleties in the messages that are understood. However, simply saying that the risks are high or the risk is 7.5 would not explicitly convey the potential consequences and policy repercussions.

A decision could still be made to keep the *status quo* or to implement the proposed management scenario as is. Or, a decision could be made to keep the current management scenario and include some of the measures from the proposed scenario as an improvement to the current approach. The decision could be a combination of several approaches given the different policy repercussions that are involved. However, a decision to do nothing is still a decision.

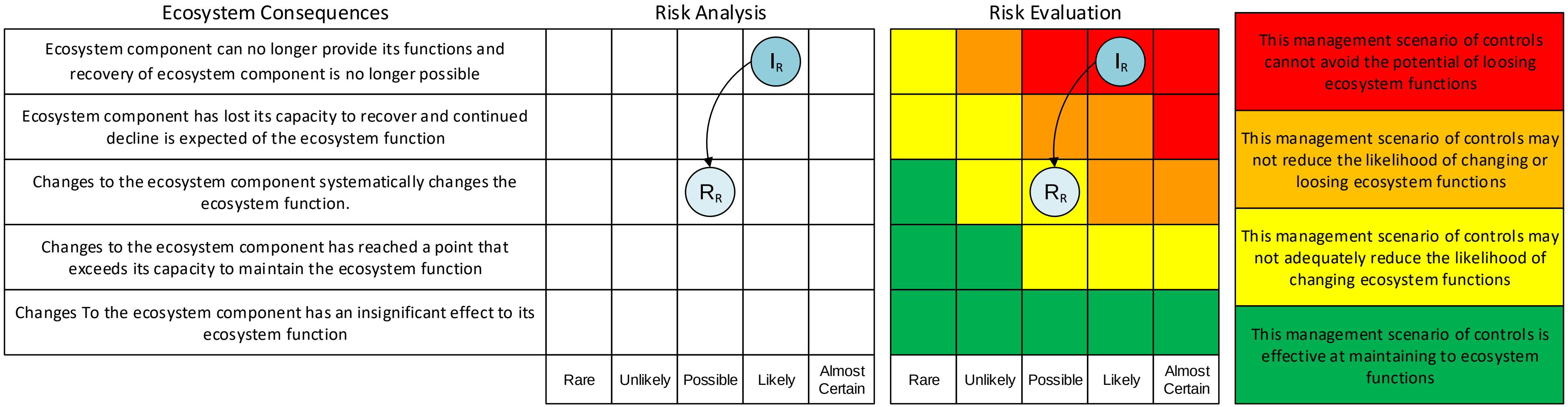


Figure 16. Ecosystem risk matrix of repercussions to ecosystem-based policy objectives.

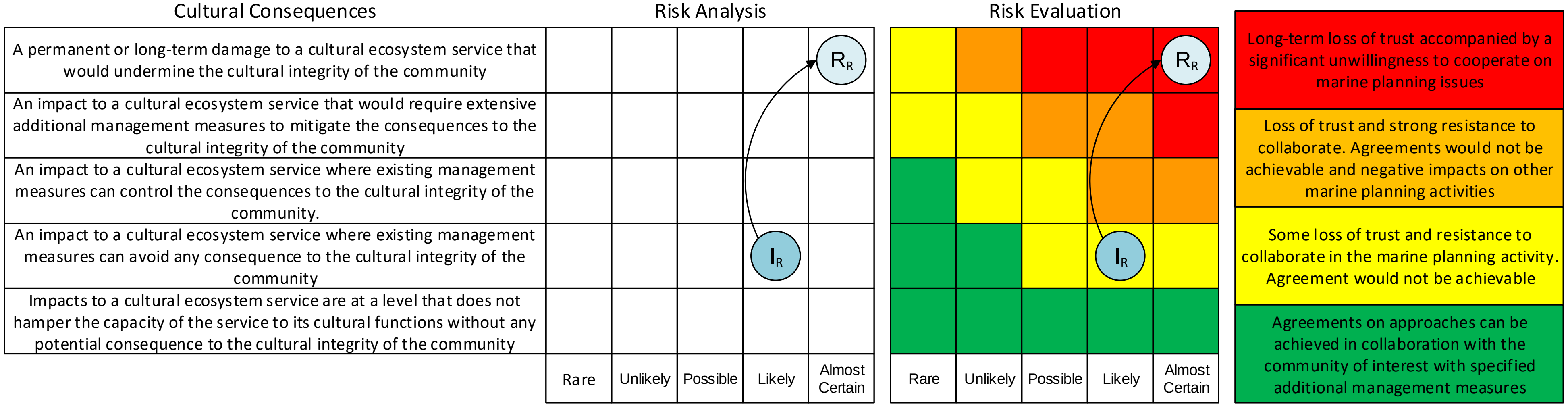


Figure 17. Cultural risk matrix of repercussions to cultural policy objectives.

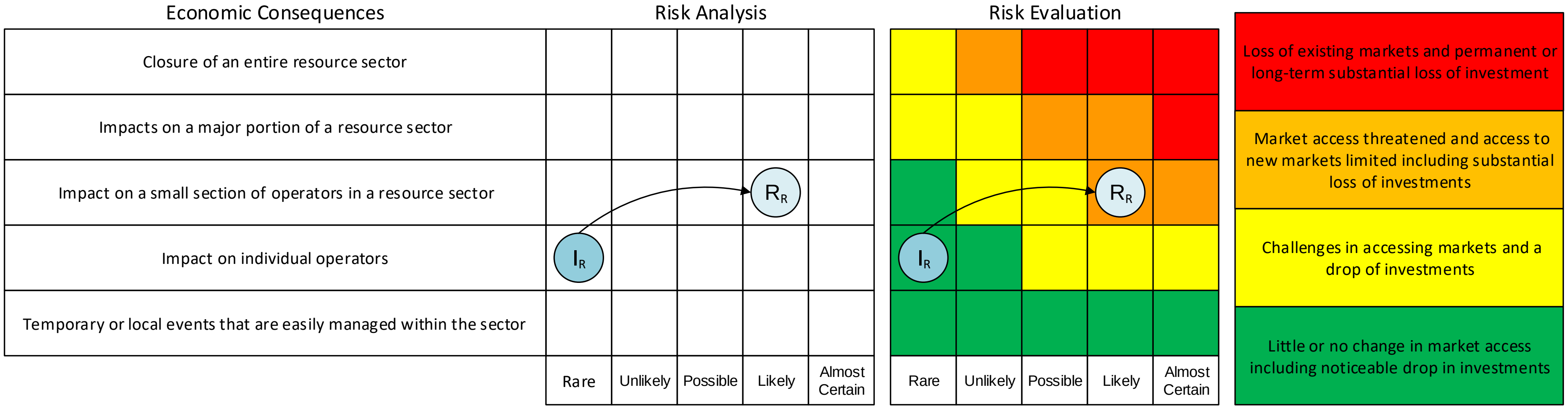


Figure 18. Economic risk matrix of repercussions to economic policy objectives.

Given that the risk matrix is used by managers or planners to formulate a recommendation in consultation with regulators, stakeholders, the person that is delegated to ultimately make a decision is presented with a structured narrative of the trade-offs and repercussions of the different management scenarios being recommended (Conroy and Emerson, 2014). It does not remove the personal challenges for the person making such a decision. Using a risk criteria, the narrative describes the evidence in terms of the values expressed in policy in contrast to individual concerns and values. A decision under uncertainty is a cognitive process of judgement and values and is the reason why data, models, and knowledge alone including the risk matrix cannot make decisions (Conrad and Ferson, 1999).

This is the challenge when using any decision-support tools to inform those that would be evaluating management scenarios and making the decision (Davies et al., 2013; Piet et al., 2017). As mentioned at the beginning of this section, there is much if not more attention needed to develop explicit and policy relevant criteria for decision-making because of the weight they carry and the hidden values they might convey in decision-making.

4.6 Treating causes and consequences to achieve the objectives

Risk treatment is basically the implementation of the suite of management measures of the management scenarios that was selected in risk evaluation. Here, it is the regulators that take the lead to integrate those measures into the standards, codes of practices and guidelines that are part of their respective environmental protection or conservation regulatory frameworks (#06 Cormier and Kannen, 2019; #12 Cormier et al., 2015). They have to determine how to efficiently implement such measures in the daily activities of their industry sector while ensuring that the expected outcomes of those measures are still being met once implemented. They would also have to determine how conformity and compliance should be addressed in addition to the need for additional training of regulatory staff and sector employees including updating procedural manuals. This may also require the purchase of new technologies that would have to be tested before going online in their daily activities. Thus, there could be a significant time-lag between the time the decision was made and the operational implementation of the new measures.

In a marine planning context, this would also require formal agreements with the competent authorities that would be implementing the measures through their legislative authorities and regulatory frameworks (Canada, 2007; Scotland, 2018). In cases where there would need to be a change made to a regulation, there could also be a need to conduct regulatory impact assessments and public consultations. Such agreements are required to ensure that the plan would follow through to implementation by the signatory of the plan.

This section does not spend a significant amount of time discussing risk treatment as there are well-established regulatory and non-regulatory processes that are currently in use (OECD, 2008).

4.7 Monitoring effectiveness to review the performance of the management scenario in achieving objectives

In risk management, monitoring activities are implemented to generate the necessary data and information to review the performance of the management scenario in achieving its objectives and reaching its strategic goals (Jabnoun et al., 2003; Otley, 1999; Tung et al., 2014). In a Bow-tie setting, this implies that monitoring needs to verify that the prevention controls are reducing the likelihood of an event and that the mitigation and recovery controls are reducing the magnitude of the consequences of such an event (Khakzad et al., 2012). A comprehensive monitoring strategy would also include monitoring and follow-up of the causes, the events and the consequences (Cockshott, 2005; Saud et al., 2014). Moreover, the performance of the management scenario cannot be ascertained without additional information from conformity assessments of the implemented controls (Pendrill, 2014), compliance surveillance of those having to implement the controls (Shimshack and Ward, 2008), and reliability studies of the controls operating over long periods of time (Tobias and Trindade, 2012).

In marine management, the situation is not as simple as managing risks within the boundaries of a manufacturing or petrochemical processing plant even though they do provide food for thought. There are many more external factors that can have an effect on the effectiveness of the controls implemented to manage human activities and their pressures as well as the measures implemented to conserve ecosystem structures and functions such as a marine protected area. However, we may not be getting the full picture of the marine management problem through piecemeal monitoring approaches from regulatory environmental effects monitoring or assessments of effects and impacts to marine ecosystems that are not integrated as part of a comprehensive environmental protection and conservation monitoring strategy (Figure 19) (#05 Cormier and Lonsdale, 2019).

The results of monitoring activities in the marine environment are affected by natural variability and the effects of climate change (Elliott et al., 2015; Saul et al., 2016). As mentioned in risk analysis, environmental protection regulatory frameworks manage activities and their pressures in contrast to conservation measures that manage or prohibit activities in relation to an ecosystem structure and function. Therefore, a monitoring strategy should integrate monitoring activities and their indicators across the causal pathways of effects from the activities and their pressures, to the residual pressures of their controls, to the degree of perturbation of vulnerable ecosystem components and environment status (Figure 19) (#05 Cormier and Lonsdale, 2019). Acknowledging the scientific and technical challenges of such an approach, the Bow-tie analysis can at least structure the several types of monitoring activities to develop a monitoring strategy for each of the risks identified and the controls implemented. (#04 Cormier et al., 2019).

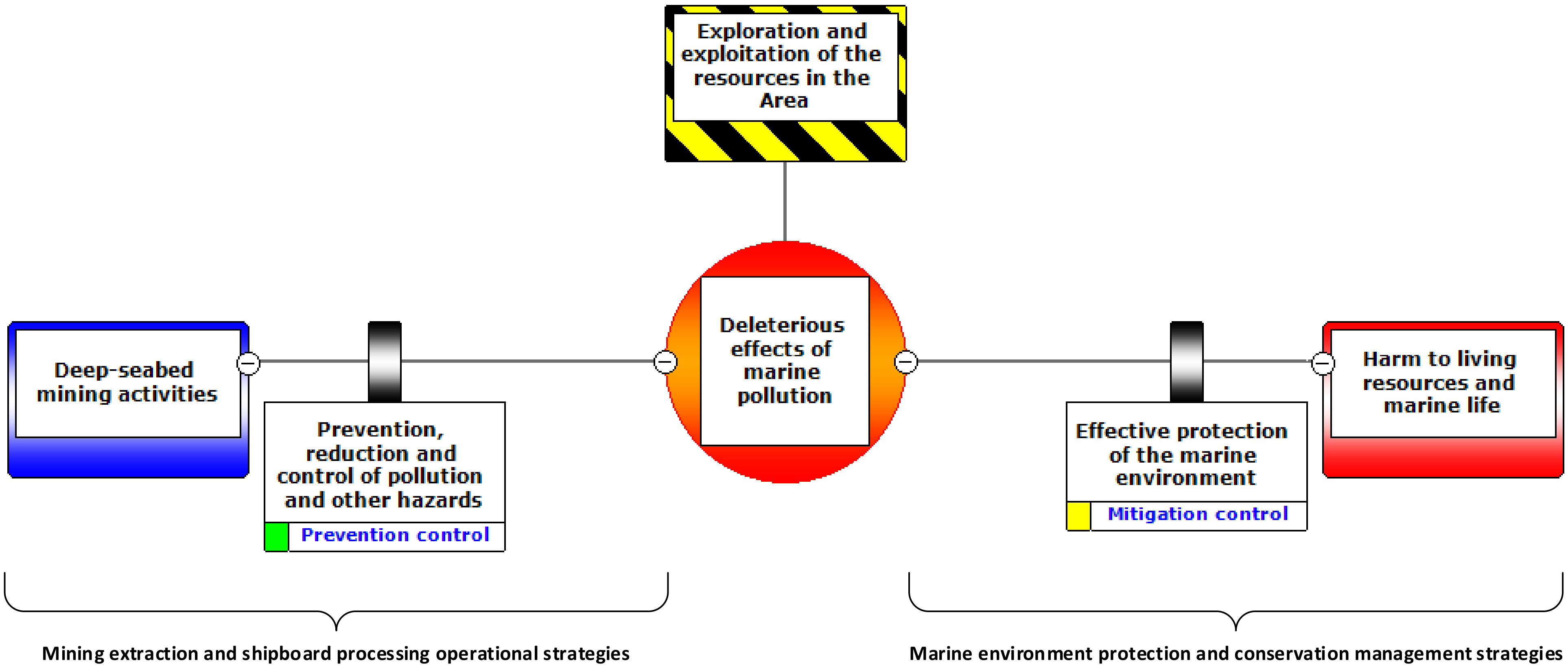


Figure 19. Horizontal integration of environmental protection regulatory frameworks and conservation strategies (#05 Cormier and Lonsdale, 2019).

Using the MSFD programme of measures, Figure 20 structures the MSFD within a monitoring Bow-tie structure. This Bow-tie reads as human activities and demands for natural ecosystem services generate multiple pressures that can exceed the output control and have an effect on the good environmental status. As the environmental protection strategies, the input controls and the spatial and temporal distribution controls are used to manage the human activities and their pressure to reduce the likelihood of exceeding the output control. As for the conservation strategies, the mitigation and remediation tools are used to reduce the effects on good environmental status. As mentioned earlier, this Bow-tie is a generic representation of the risk management structure e of the MSFD (#08 Cormier et al., 2018).

In risk-based approaches to performance management (Giraud et al., 2011; Girling, 2013; Green, 2015), key indicators are used to track and review performance among the indicators used to manage an enterprise (#03 Cormier and Elliott, 2017).

- Key Risk Indicators (‘KRIs’) indicate a change in the probability or likelihood of impacts of a risk that would undermine objectives.
- Key Control Indicators (‘KCIs’) indicate a change in the effectiveness of the controls in meeting an expected outcome or result.
- Key Performance Indicators (‘KPIs’) indicate changes in the organizational performance reaching its strategic goals.

Applying these categories to the Bow-tie structured of the MSFD (Figure 20), the initial pressures generated by human activities before the controls could be considered as the Key Risk Indicators. An indicator would be needed for each pressure (e.g. MSFD Annex III Table 2) such as shown in Figure 12 and Figure 13 for seafloor integrity and eutrophication. The total residual pressures could be the Key Control Indicator of the effectiveness of the input controls and spatial and temporal distribution controls implemented across the environmental protection regulatory frameworks as a measure of the degree of perturbation of the ecosystem component and status of its function (#02 Cormier et al., 2018). The Key Performance Indicators could be the indicators for good environmental status based on the current criteria and methodological standards of the directives (EC, 2017b, 2010b). Here, the Key Performance Indicators would also have to include indicators for the effectiveness of the mitigation and remediation tools given that these are intended to restore the damaged ecosystem components of the marine environment to achieve and maintain good environmental status.

As Key Performance Indicators, not achieving or maintaining good environmental status would imply that the environmental protection and conservation strategies are not effective. As Key Control Indicators, exceeding the output control would be an indication that the environmental protection strategies are not effective. As Key Risk Indicators, it could also be an indication that the initial pressures of increasing human activities have exceeded the capacity of the environmental protection strategies to reduce the total residual pressures to levels below the output control. Following the convention of the Bow-tie, the key indicators provide a useful hierarchy of indicators to monitor the root causes of risk (initial pressures), the effectiveness of the prevention controls (e.g. total residual pressures), the event of failing prevention controls (e.g. output control) and the consequences of such an event (e.g. good environmental status). Key indicators could help develop an integrated monitoring strategy by defining the roles of the indicators and the aspect of the risks they track.

Using the Bow-tie definition for prevention, mitigation and recovery controls (Figure 7), conservation strategies are considered as mitigation and recovery controls. Using the definitions for the expected outcome of the mitigation and remediation tools of the MSFD (Figure 20), one could argue that conservation strategies do more than simply restore damaged ecosystem components. Indeed, the implementation of marine protected areas is to protect unique or significant ecosystem structures, functions and processes most often considered as pristine areas. Given that environmental protection strategies manage human activities and their pressures to reduce the collective pressures on the ecosystem at large, conservation strategies such as marine protected areas are technically mitigation controls to reduce the magnitude of the impacts to such unique or significant ecosystem components. Restoration activities would be identified as recovery controls to restore the damaged ecosystem components. This is where the definition for the MSFD mitigation and remediation tools do not strictly follow the Bowtie convention as these would be considered recovery controls.

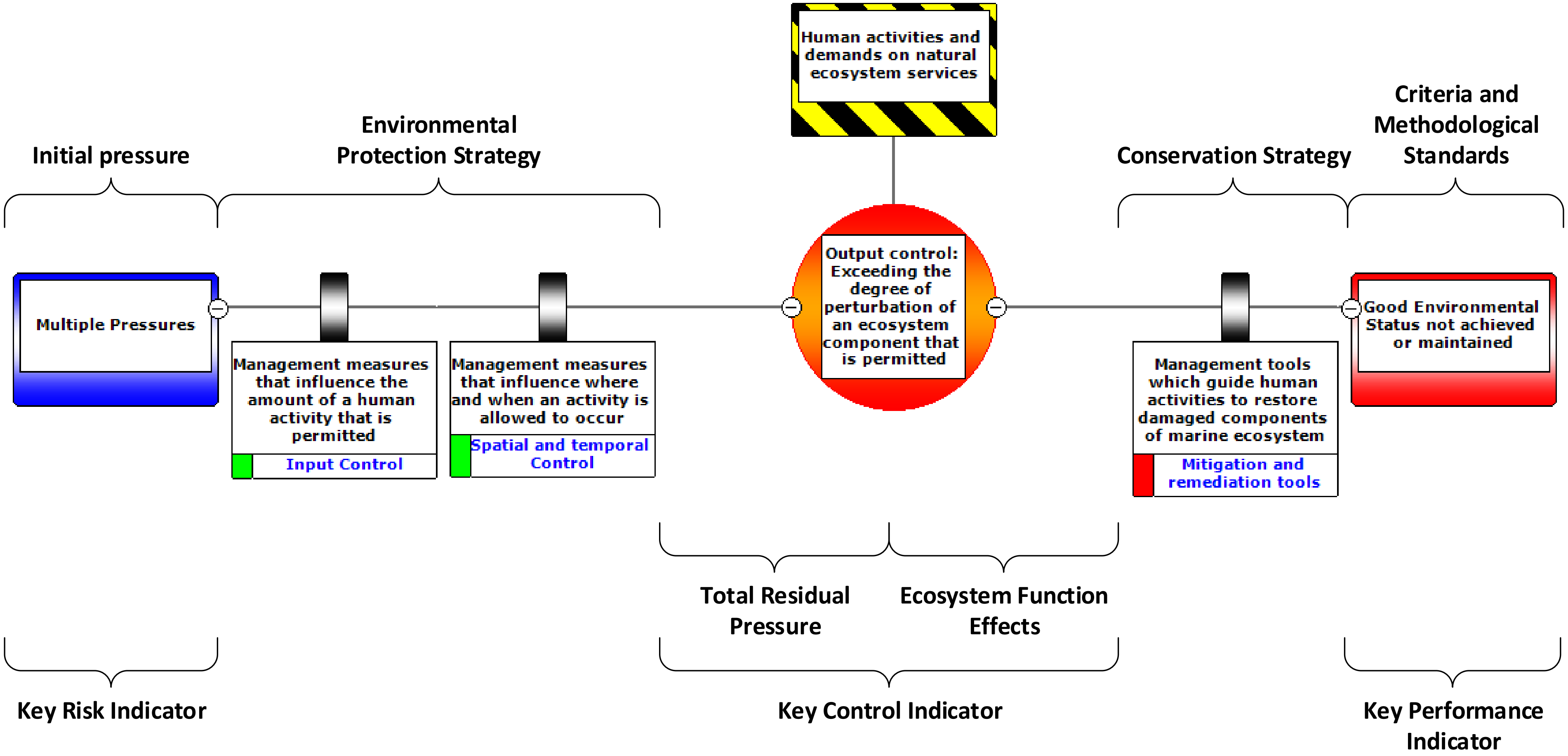


Figure 20. Key risk, control and performance indicators approaches for the MSFD.

The most significant challenge to develop such indicators is our current difficulties to combine multiple pressures (e.g. seafloor integrity Figure 12), with the effectiveness of multiple environmental protection strategies to estimate the total residual pressure (#02 Cormier et al., 2018; Stelzenmüller et al., 2010). Although mapping human activities is considered as indicators of marine ecosystem vulnerabilities (Halpern, 2009), cumulative effects assessments are still challenged by the need to link these assessments the cumulative pressures that need to be managed (ICES, 2019; Stelzenmüller et al., 2018). As discussed above for marine protected areas, conservation strategies are often assumed to maintain ecosystem structure, functions and processes in a bioregional context while they are mostly mitigating the effects within their controlled area (#02 Cormier et al., 2018). Although ecologically and biologically significant areas and species may help identify the ecosystem components and functions of concern for the output control, establishing indicators and thresholds needed to maintain their functions as well as their contribution to the overall ecosystem functions and processes is also a challenge (Figure 14).

Despite the above, there is an even greater challenge to establish the causal relationship between these indicators and environmental status because of external factors such as climate change and natural variability (Berg et al., 2015; Borja et al., 2013; Rice et al., 2012). Following the Bow-tie conventions for escalation factors and cascading events (Figure 9), the Bow-tie analysis of the MSFD (Figure 21) links impacts and effects from external factors that could undermine the effectiveness of the environmental protection and conservation strategies. The Bow-tie shows that the consequences of the cascading events (Red boxes in the lower left side) such as the pressures from outside the management area, the effects of climate change and natural variability contribute directly to the degree of perturbation of the ecosystem component and, thus, could exceed the output control in combination with the total residual pressures (#02 Cormier et al., 2018). The same three consequences of cascading events could also undermine the effectiveness of the mitigation and remediation tools. It should be noted that these three consequences could also undermine the effectiveness of the input controls and the spatial and temporal distribution controls. These are not shown here to keep the diagram manageable in this document. Continuing with the rationale behind the consequences of cascading events, cases where good environmental status is not achieved or maintained for specific descriptors could also have an effect on the biological diversity of the management area (#08 Cormier et al., 2018). Rather, it could have an effect on Descriptor 1 for biological diversity.

This version of the MSFD Bow-tie presents significant repercussions for monitoring strategies. As a Key Performance Indicator, not achieving or maintaining good environmental status would not necessarily be an indication of ineffective environmental protection and conservation strategies given that the effects from these other external factors are hidden in the indicator used in monitoring. A similar situation could be occurring for the Key Control Indicators for the total residual pressures. Changes could be occurring to the functions of the ecosystem component used for the output controls because of a greater degree of perturbation generated by these external factors (Elliott et al., 2015). Finally, an increase in the initial pressures used as Key Risk Indicators could also be caused by these external factors and not because there has been an increase in human activities in the management area.

Given that the prevention controls in a Bow-tie are the key for a proactive management strategy, particular attention would have to be given to the Key Control Indicators and the Key Risk indicator as these are the bookends between the initial pressures generated by human activities at large and the total residual pressures that is generated from the level of effectiveness of the environmental protection regulatory frameworks. The selection of these indicators would have to minimize the influence of these external factors as best as it could be (Boyes and Elliott, 2014). Coupled with the results from conformity assessments, compliance surveillance and reliability studies, such indicators are essential for the review of the effectiveness of these regulatory frameworks to identify improvements regarding their standards, codes of practice or guidelines.

As for monitoring ecosystem structures, functions and processes, the challenge in these monitoring activities lie in the use of surrogate metrics as indicators of productivity and biodiversity (DFO, 2019b). Indicators are sometimes constrained by the aspects of a project impact or ecosystem effects to be monitored and the sampling design and protocols to measures them. Indicators should be a measure of the expected outcomes of the controls as described by MSFD programme of measures. In most cases, it likely requires a suite of reliable indicators to fully describe an impact or an effect that includes an appreciation of the spatial and temporal variabilities. Using the structure of the Bow-tie and the key indicators may provide valuable insight to what an indicator may be indicating (Aubry and Elliott, 2006; Rice and Rivard, 2007).

After the central event of the Bow-tie (e.g. output control), it is clear that the indicators used for monitoring in an ecosystem context may not effectively discriminate the impacts and effects of the environmental protection and conservation strategies from the impacts and effects causes by external factors such as those discussed above. The external factors introduce impacts and effects that are outside the span of control of the management strategies of a given jurisdiction as represented by the Bow-tie diagram (Borja et al., 2013; Elliott and Quintino, 2007). For example, the effects of climate change are likely shifting baselines and undermining the reliability of the indicators being used (Elliott et al., 2015). Monitoring without clearly understanding what is actually being monitored can provide a false sense of security that has even been coined as “comfort monitoring” (Noble and Birk, 2011). Given the complexity of factors that can influence monitoring results, we may have reached the limits of our deterministic approach to predict impacts and effects as we may be experiencing a chaotic system that cannot be predicted by our scientific reductionist approaches (Sapolsky and Balt, 1996).

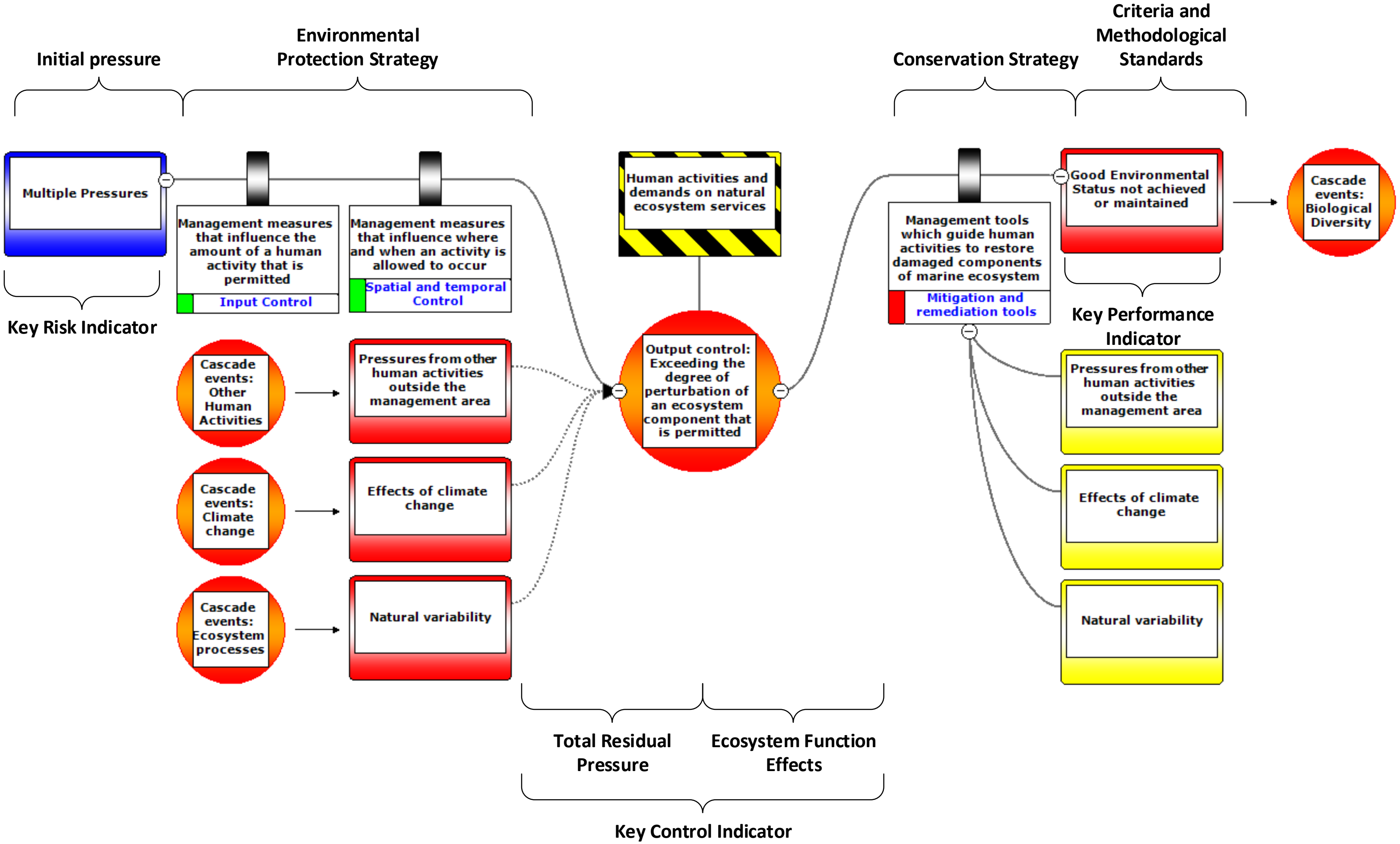


Figure 21. Effects of cascading event and escalation factors in monitoring.

5 Discussion

Risk management standards and tools have been around for decades. They should not be seen as a panacea to solve current marine management problems (#06 Cormier and Kannen, 2019). Rather, they should be seen as processes and tools to structure the marine management problem within the context and scope of a policy (#07 Cormier, 2019). The scope of the policy plays an important role in identifying the risks to avoid the never ending quest for more data and discussions (#04 Cormier et al., 2019). Given that risk is the effect of uncertainty on achieving the objectives, the risk management process cannot reduce all of the uncertainties of risk to zero (#05 Cormier and Lonsdale, 2019). It can only help evaluate management scenarios to reduce those risks as low as reasonably practicable given the uncertainties that are inherent to the scientific knowledge, the management and decision-making processes and ultimately operational implementation of the controls (#02 Cormier et al., 2018; Baybutt, 2014c). Subsequently, monitoring and review provide the basis for incremental improvements to the environmental protection and conservation policies and strategies being pursued (#01 Cormier et al., 2017).

The administrations that are mandated to lead and facilitate marine planning processes have bring together the priorities of the political system, the concerns of stakeholders and the scientific and technical knowledge of experts. They have to integrate environmental, cultural, social, economic and even legal considerations into the planning activities and decision-making process. Generally, planners working in these administrations come from very different educational backgrounds and disciplines that can influence the thematic approaches in planning. For discussion purposes, an ecologist would seek ecological solutions in planning while an economist would seek an economic solution or a lawyer a legal solution while all three are needed equivocally. Moreover, leadership skills can only go so far because a planning initiative relies heavily on administrative procedures that can include terms of references, record keeping, budget tracking and coordination of communication, consultation and advisory processes. More importantly, it also needs clarity as to who makes the decisions and who makes the recommendations to be considered for those decisions in respect of the transparency expectations of stakeholders and the public.

Everyone involved in marine planning does so with the best intentions. A notable impediment to many marine planning is related to a lack of formalized processes for the competent authorities that are given the mandate to lead such process (#12 Cormier et al., 2015). Rightfully so, the predominant preoccupation with ecosystem impacts and effects can time draw attention away from the other cultural, social and economic preoccupations in marine planning (#06 Cormier and Kannen, 2019). ISO 31000 risk management standards is not being promoted here as the best risk management framework. The value of such standards in marine planning is that it provides a generic risk management process that is not biased towards any of the environmental, cultural, social or economic values and approaches that interplay in marine planning. More importantly, the process is driven by policy instead of stakeholder concerns and scientific knowledge. This is not to say that stakeholder concerns and scientific knowledge are not important. The caveat here is that the policy scopes the concerns that can be addressed by the planning process and the knowledge that is needed to inform the process.

Formalized scientific advisory processes are also as important as formalized marine planning processes for the competent authorities. Normative science can help build a knowledge base of ecological concepts and frameworks that can improve the efficiencies in of marine planning processes over time. Working with the context and scope of the policy, these concepts and frameworks can help managers and planners formulate the scientific questions within the scope of the issues they are trying to address. Although the ecosystem-based approach is critical of current piecemeal approaches to sector, activity or species management regimes, the same can be said of the repercussions of piecemeal approaches to management questions and scientific advice. Normative science is used in other science based programs such as seafood safety (#19 Cormier et al., 2007; #20 Valdimarsson et al., 2004). There would have to be similar advisory processes for cultural, social, and economic considerations given the broader scope of objectives in marine planning.

Risk management tools such as the Bow-tie analysis are not intended to simplify complexity. The complexity of marine ecosystems and marine management cannot be simplified by a simple diagram. These tools structure the complexity within a management context to help understand the issues and inform the assessment processes needed to identify the management options that could be implemented to achieve objectives (#04 Cormier et al., 2019). However, the Bow-tie analysis is a valuable tool to structure the management systems of environmental protection and conservation strategies to finds way to better integrate them (#07 Cormier, 2019; #08 Cormier et al., 2018; #13 Cormier et al., 2016). However, it is through their regulatory frameworks that the policies are carried into effects (#01 Cormier et al., 2017).

The Bow-tie does introduce an important set of conventions and definitions for marine environmental protection and conservation strategies. The predominance of adaptive management and social resilience discussion practically creates an illusion that society does not need to worry as it will only need to adapt as things change in the pursuit of their opportunities. The Bow-tie convention of a proactive management strategy does teach us an important lesson. The occurrence of an event is considered as a failure of a proactive management strategy or a loss of control of the prevention controls. As a reactive management strategy, mitigation and recovery controls are not to be considered as part of the *modus operandi*. Following this line of thinking, a reactive management strategy based on piecemeal mitigation and restoration measures could ultimately lead to a situation where there are no impacts or effect left to mitigate or restore.

6 Conclusions

After more than 10 years of discussion and trying standardized risk management processes and tools, marine planning is still a hodgepodge of processes, science and stakeholder participation. It is understandable that the challenge for someone having to make a decision under uncertainty is what drives use to seek more data, information, feedback and advice. In risk management and some engineering realms, there comes a point where additional information does not reduce uncertainty by orders of magnitude where practical common sense has to prevail.

The operational implementation of the ecosystem-based approach to management is not only about integration of policies. It is about integration of the environmental protection and conservation regulatory frameworks. A risk management process works from the policy context to scope the risks to be assessed and identify the management measures to reduce those risks. The process does not select the management measure *a priori* and then does an assessment to justify the measure. It could be the wrong management measure given the risks that need to be reduced such as contaminants versus seafloor integrity. Although marine protected areas are a very important tool in marine conservation, the rush to establish marine protected areas without fully understanding how pressures are reduced by existing environmental protection regulatory frameworks may undermine the very protection being sought by such conservation measure. However, the same can be said for environmental protection regulatory frameworks. A marine process should not start with the premise that new standards, codes of practice and guidelines are needed. The process seeks find improvements to current regulatory frameworks and considers adding additional layers of regulations where it is needed.

Although there has been significant academic research in the natural sciences regarding the ecosystem approach and in the social sciences regarding stakeholder engagement in environmental studies, there has not been as much academic attention given to what the schools of management, administration and law have to offer in a marine planning process. Most of the discussions in this thesis have more to do with management, administration and regulatory processes and policies. The word management in ecosystem-based management implies the use of management concepts and principles as does planning imply the use of planning and administration processes. Standards, codes of practice and guidelines implies the use of engineering approaches to technical solutions. In response to a query about the education provided by academic institutions for those that are seeking a career in environmental management and planning, I suggest that management and planning is not about studying the problem. It is about analysing the problem to find management solutions. Once solution would be to devise an MSc/MA in environmental administration similar to a Master's in Business Administration or Public Administration. Management and planning is more in need of generalist that understand a broad range of disciplines than a specialist that will try to find solutions through their specialization.

However, we may have reached a point where policy solutions to environmental management shortcomings may not be sufficient given the tremendous pressures exerted by human activities on the marine environment. We may need a more technical approach based on prevention similar to other risk management contexts from flying an airplane to food safety.

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Annex 1 List of Published Work

Listed in the order of importance for the treatise of the subject matter in this thesis, the following published papers and book chapters are submitted as evidence for the author to be examined for award of a PhD by published work at the University of Hull. The supplementary published works are provide as additional evidence but are considered to be outside the scope of this thesis and as such are not intended to be examined directly. Testimonials for the specific contributions of the authored papers and chapters as also provided.

Published papers

#01 **Cormier**, R., Kelble, C.R., Anderson, M.R., Allen, J.I., Grehan, A., Gregersen, Ó., 2017. Moving from ecosystem-based policy objectives to operational implementation of ecosystem-based management measures. ICES J. Mar. Sci. 74, 406–413. https://doi.org/10.1093/icesjms/fsw181

#02 **Cormier**, R., Stelzenmüller, V., Creed, I.F., Igras, J., Rambo, H., Callies, U., Johnson, L.B., 2018. The science-policy interface of risk-based freshwater and marine management systems: From concepts to practical tools. J. Environ. Manage. 226, 340–346. https://doi.org/10.1016/j.jenvman.2018.08.053

#03 **Cormier**, R., Elliott, M., 2017. SMART marine goals, targets and management – Is SDG 14 operational or aspirational, is 'Life Below Water' sinking or swimming? Mar. Pollut. Bull. 123, 28–33. https://doi.org/10.1016/j.marpolbul.2017.07.060

#04 **Cormier**, R., Elliott, M., Rice, J., 2019. Putting on a bow-tie to sort out who does what and why in the complex arena of marine policy and management. Sci. Total Environ. 648, 293–305. https://doi.org/10.1016/j.scitotenv.2018.08.168

#05 **Cormier**, R., Lonsdale, J., 2019. Risk assessment for deep sea mining: An overview of risk. Mar. Policy. https://doi.org/10.1016/J.MARPOL.2019.02.056

Book chapters

#06 **Cormier**, R., Kannen, A., 2019. Managing risk though marine spatial planning, in: Zaucha, J., Gee, K. (Eds.), Marine Spatial Planning Past, Present, Future. Palgrave MacMillan, pp. 353–373. https://doi.org/10.1007/978-3-319-98696-8

#07 **Cormier**, R., 2019. Ecosystem approach for management of deep-sea mining activities, in: Sharma, R. (Ed.), Environmental Issues of Deep-Sea Mining: Impacts, Consequences and Policy Perspectives. Springer International Publishing, Cham, Switzerland, pp. 381–402.

Published papers used as supporting literature

#08 **Cormier**, R., Elliott, M., Kannen, A., 2018. IEC/ISO 31010 Bow-tie analysis of marine legislation: A case study of the Marine Strategy Framework Directive. ICES Coop. Res. Rep. 342, 63.

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#10 Astles, K., **Cormier**, R., 2018. Implementing Sustainably Managed Fisheries Using Ecological Risk Assessment and Bowtie Analysis. Sustainability 10, 3659. https://doi.org/10.3390/su10103659

#11 **Cormier**, R., Kannen, A., Elliott, M., Hall, P., Davies, I.M., 2013. Marine and coastal ecosystem-based risk management handbook. ICES Coop. Res. Rep., Cooperative Research Report 317, 64.

#12 **Cormier**, R., Kannen, A., Elliott, M., Hall, P., 2015. Marine Spatial Planning Quality Management System. ICES Coop. Res. Rep. 327, 111.

#13 **Cormier**, R., Savoie, F., Godin, C., Robichaud, G., 2016. Bowtie analysis of avoidance and mitigation measures within the legislative and policy context of the Fisheries Protection Program. Can. Manuscr. Rep. Fish. Aquat. Sci. 3093, 38.

#14 **Cormier**, R., 2019. Waste Assessment Guidance: Bow-tie analysis and cumulative effects assessment, Scientific Group of the London Protocol.

#15 Creed, I.F., **Cormier**, R., Laurent, K.L., Accatino, F., Igras, J.D.M., Henley, P., Friedman, K.B., Johnson, L.B., Crossman, J., Dillon, P.J., Trick, C.G., 2016. Formal Integration of Science and Management Systems Needed to Achieve Thriving and Prosperous Great Lakes. Bioscience 66, 408–418. https://doi.org/10.1093/biosci/biw030

#16 Gee, K., Kannen, A., Adlam, R.G., Brooks, C., Chapman, M., **Cormier**, R., Fischer, C., Fletcher, S., Gubbins, M., Shucksmith, R., Shellock, R., 2017. Identifying culturally significant areas for marine spatial planning. Ocean Coast. Manag. 136, 139–147. https://doi.org/10.1016/j.ocecoaman.2016.11.026

#17 Gimpel, A., Stelzenmüller, V., **Cormier**, R., Floeter, J., Temming, A., 2013. A spatially explicit risk approach to support marine spatial planning in the German EEZ. Mar. Environ. Res. 86, 56–69. https://doi.org/10.1016/j.marenvres.2013.02.013

#18 Aps, R., Herkül, K., Kotta, J., **Cormier**, R., Kostamo, K., Laamanen, L., Lappalainen, J., Lokko, K., Peterson, A., Varjopuro, R., 2018. Marine environmental vulnerability and cumulative risk profiles to support ecosystem-based adaptive maritime spatial planning. ICES J. Mar. Sci. https://doi.org/10.1093/icesjms/fsy101

#19 **Cormier**, R., Mallet, M., Chiasson, S., Magnússon, H., Valdimarsson, G., 2007. Effectiveness and performance of HACCP-based programs. Food Control 18, 665–671. https://doi.org/10.1016/j.foodcont.2006.02.019

#20 Valdimarsson, G., **Cormier**, R., Ababouch, L., 2004. Fish Safety and Quality from the Perspective of Globalization. J. Aquat. Food Prod. Technol. 13, 103–116. https://doi.org/10.1300/J030v13n03_10

Testimonials for Co-authored Published Work

#01 Cormier, R., Kelble, C.R., Anderson, M.R., Allen, J.I., Grehan, A., Gregersen, Ó., **2017**. Moving from ecosystem-based policy objectives to operational implementation of ecosystem-based management measures. ICES J. Mar. Sci. 74, 406–413. https://doi.org/10.1093/icesjms/fsw181.

Contribution to the field: This paper introduces the importance of regulatory frameworks to operationalize ecosystem-based management providing clarity as the problems of implementation that is currently discussed as a problems of governance and policies. It describes the differences between the roles policymaking, planning and regulatory processes to the in marine planning and implementation based on policymaking approaches.

This paper is part of a special series of the ICES Journal of Marine Science on operationalizing ecosystem-based management as a result of a workshop on operationalizing ecosystem-based management organized by the Atlantic Ocean Research Alliance Support Action and the International Council for the Exploration of the Sea (ICES).

From: Mark Dickey-Collas Mark.dickey-collas@ices.dk
Date: 01/28/2016 07:50AM
Cc: Jason Link <jason.link@noaa.gov>, Howard Browman <Howard.browman@imr.no>

Subject: Invitation to submit to the ICES journal

(See attached file: Invitation to contribute to an ICES JMS article theme set on EA_Revised_....doc)

Dear Participant in the workshop on making the ecosystem approach operational, Please see attached an invitation to submit a manuscript to the ICES Journal of Marine Science for a theme section on “Case studies in operationalizing ecosystem-based management”.

Best regards

Dr Mark Dickey-Collas
Ecosystem Approach Coordinator
International Council for the Exploration of the Sea (www.ices.dk)
Copenhagen, Denmark

Associate Professor DTU- Aqua (http://www.aqua.dtu.dk/english)
Twitter: @DickeyCollas
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Phone: +45 33386759 Mobile: +45 31415578

#02 Cormier, R., Stelzenmüller, V., Creed, I.F., Igras, J., Rambo, H., Callies, U., Johnson, L.B., **2018**. The science-policy interface of risk-based freshwater and marine management systems: From concepts to practical tools. J. Environ. Manage. 226, 340–346. https://doi.org/10.1016/j.jenvman.2018.08.053.

Contribution to the field: This paper introduces the need to quantity the effectiveness of management measures implemented by industry sectors using the residual pressure as the indicator of effectiveness. Given that the literature is very sparse on this subject matter, the paper highlights the importance of improving the effectiveness of regulatory frameworks to address cumulative impacts to address cumulative effects in the marine environment. Borrowing from engineering approaches, it introduces the use of the Bow-tie analysis as the management structure used for the nodes in a Bayesian Belief Network to quantify the effectiveness of the measures and calculate the residual pressure.

This paper is the output of three years of workshops on the use of the Bow-tie approach and Bayesian Belief models in cumulative effects assessments. The work was part of the ICES Work Group on Marine Planning and Coastal Zone management.

Workshop on Bayesian Belief Network Case Studies (WKBNCS)

2015/2/SSGEPI12 Workshop on Bayesian Belief Network Case Studies (WKBNCS), chaired by Roland Cormier, Canada, and Vanessa Stelzenmüller, Germany, will meet in London, Ontario, Canada, 26–30 September 2016 to:

a) Review the results of the North American and European case studies undertaken to refine the Bayesian Belief Network meta-models;
b) Refine the meta-model to assess the performance of the system of management measure in reducing pressures;
c) Characterize and integrate residual pressures as input into ecological deterministic and Bayesian models to analyse impacts of management measures.

WKBNCS will report by 15 November 2016 in collaboration with WGMPCZM (via SSGEPI) for the attention of SCICOM. Further output from the workshop will be developed together with WGMPCZM such as **peer reviewed papers** and/or a Cooperative Research Report on the use of the methods and the new research areas being identified.

#03 Cormier, R., Elliott, M., **2017**. SMART marine goals, targets and management – Is SDG 14 operational or aspirational, is 'Life Below Water' sinking or swimming? Mar. Pollut. Bull. 123, 28–33. https://doi.org/10.1016/j.marpolbul.2017.07.060.

Contribution to the field: This paper discusses the issues of national regulatory implementation of the United Nations Sustainable Development Goal 14 for oceans. It identifies the lack of specificity (SMART) of aspirational goals and targets as the problem for implementation risk-based regulatory frameworks. Borrowing from the finance community, it also introduces the use of key risk indicators as a novel approach to align indicators that are currently used in ecosystem-based monitoring as risk indicators used in risk management processes.

As the chair of two ICES and UN on Sustainable Development Goal 14 'life below water' organized by the United Nations Economic Commission for Europe, the paper is an overview of the workshop discussions.

#04 Cormier, R., Elliott, M., Rice, J., **2019**. Putting on a bow-tie to sort out who does what and why in the complex arena of marine policy and management. Sci. Total Environ. 648, 293–305. https://doi.org/10.1016/j.scitotenv.2018.08.168.

Contribution to the field: This paper introduces the Bow-tie analysis as a tool to horizontally integrate environmental protection regulatory frameworks with conservation measures. Given the increasing uses of the Bow-tie analysis in marine management in the literature, the paper provide a guide for those using this approach in ecosystem-based management and marine planning.

This paper is the state of the art of the Bow-tie analysis in freshwater and marine ecosystem-based management and planning given the attention for this technique in the literature.

#05 Cormier, R., Lonsdale, J., **2019**. Risk assessment for deep sea mining: An overview of risk. Mar. Policy. https://doi.org/10.1016/J.MARPOL.2019.02.056.

Contribution to the field: This paper introduces the use of risk management processes and Bow-tie analysis to identify the risks in deep-seabed mining. It demonstrates the application of these concepts to develop environmental management strategies for deep-seabed mining. It introduces the need to horizontally integrate the regulatory frameworks used to manage this sector with conservation strategies. Borrowing from engineering, it also introduces the use of risk criteria and risk matrices for the evaluation and selection of the management scenario.

This paper is part of a special series of Marine Policy on deep-seabed mining as a result of a workshop organized by the Institute for Advanced Sustainability Studies and the German Department of the Environment in collaboration with the UN International Seabed Authority.

To: Cormier Roland Roland.Cormier@hzg.de
From: Sabine Christiansen sabine.christiansen@iass-potsdam.de
Date: 07/06/2017 08:22AM
Subject: Risk assessment DSM

(See attached file: Ws report Cormier.docx)

Dear Roland,

I hope you are well - and not on holidays for my sake …
I have two questions:

1. We have now finalised the Berlin workshop report, submitted to ISA, they already checked it and now need high resolution diagrams from you - see enclosed your report chapters. In particular the first figure would benefit from better readability as we cannot enlarge it.

2. We are considering to compile a special edition of Marine Policy and look out for potential contributions. As we cannot attach the background documents for the workshop to the workshop report or website (a shame!), we thought to publish the articles in an academic journal, so to say as suggestions for good governance of the Area. Do you think you could elaborate on a risk assessment framework for ISA based on your presentation in the workshop? I could offer to help if you like, as I will try to produce something on regulatory risk assessment for our final project report (by end October).

We are still in the early stages, so mid 2018 would probably a target date for having all contributions together. The papers would be published successively.

Best wishes,

Dr. Sabine Christiansen
Wissenschaftliche Mitarbeiterin Ocean Governance / Project Scientist Ocean Governance
Sustainability Governance
Institute for Advanced Sustainability Studies e.V. (IASS)
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Mail: Sabine.Christiansen@iass-potsdam.de
Web: www.iass-potsdam.de
Skype: velella5382

#06 Cormier, R., Kannen, A., **2019**. Managing risk though marine spatial planning, in: Zaucha, J., Gee, K. (Eds.), Marine Spatial Planning: Past, Present, Future. Palgrave MacMillan, pp. 353–373. https://doi.org/10.1007/978-3-319-98696-8.

Contribution to the field: This chapter establishes that marine spatial planning is a management function of administrations and not a governance function for policymaking. Given the management role of marine planning, risk management process is introduced as the means to deal with multiple environmental and socio-economic objectives in planning.

This paper is part of an initiative on marine spatial planning at the Institute for Coastal Research at Helmholtz-Zentrum Geesthacht, Germany.

An: "Jay, Stephen" <Stephen.Jay@liverpool.ac.uk>, "Kidd, Sue" <suekidd@liverpool.ac.uk>, "OHiggins, Linda" <linda.ohiggins@ucc.ie>, tim.ohiggins@ucc.ie, "Holness, S (Dr) (Summerstrand Campus South)" <S.Holness@nmmu.ac.za>, harris.linda.r@gmail.com, "Angela Schultz-Zehden" <asz@sustainable-projects.eu>, "Barbara Weig" <bw@submariner-network.eu>, "Ruth Brennan" <Ruth.Brennan@tcd.ie>, "Wesley Flannery" <w.flannery@qub.ac.uk>, "Sarah Twomey" <S.Twomey@ucc.ie>, "OMahony, Cathal" <c.omahony@ucc.ie>, "Andrea Morf" <andrea.morf@nordregio.se>, "Fred Saunders" <fred.saunders@sh.se>, "Michael Gilek" <michael.gilek@sh.se>, "Lucy Greenhill" <Lucy.Greenhill@sams.ac.uk>, "Dr. Andreas Kannen" <andreas.kannen@hzg.de>, Roland.Cormier@hzg.de, "Hannah Thomas" <Hannah.Thomas@unep-wcmc.org>, "Varjopuro Riku" <riku.varjopuro@ymparisto.fi>, "Catarina Fonseca" <catarinafonseca7@gmail.com>, "Helena Maria Gregório Pina Calado" <helena.mg.calado@uac.pt>

Von: k.gee@gmx.de
Datum: 23.11.2017 14:46
Kopie: "Jacek Zaucha" jacek.zaucha@gmail.com
Betreff: Good news MSP book, open access option and timetable

(Siehe angehängte Datei: MSP book_outline_171009.docx)
(Siehe angehängte Datei: Open Access funding table.docx)

Dear all,

We are writing with good news regarding our MSP book. After some helpful comments from two reviewers, which were mostly about the structure of the chapters, Palgrave Macmillan have accepted our proposal and are happy to publish the book, either as open access or a traditional version. They seem keen and the editor in charge of us is very supportive.

Timetable

Jacek and I are about to sign the official contract – which brings with it a serious commitment to deliver. I have no doubt that we can do this, but it does mean we ABSOLUTELY need to stick to the timetable we communicated previously. Which is as follows:

- Delivery of chapters no later than 30 April 2018
- Internal review (will suggest a way of sharing this) and revisions by 1 June 2018

- Preparation of things like an index and foreword (if needed we'll send instructions on the former)
- Handing over the final manuscript no later than 1 July 2018.

This is very ambitious, and I do hope we can manage this. Should you foresee any difficulties with this timeline at all, also at any later stages, please let me know ASAP, Also, if for some reason you feel you can no longer commit to this, please tell us now rather than later so we can try to fill the spot in another way.

Any outstanding abstracts

Those of you who haven't yet sent me an abstract could you kindly do so soonest so we can start structuring the book.

Open access option

In our last email we briefly touched upon open access. This is our preferred option, but we will need to raise GBP 11,000 between us. Palgrave have told us there is no problem with invoicing prior to publication should you need to spend your share within a certain deadline, but we do need to let them know soon whether we can raise the total. If not, there is no problem at all going back to a standard contract.

Could I therefore ask you to fill in the attached table to let me know how much you could pledge and when you would need to be invoiced by. Just put down what you consider feasible. If the total is more than we need, so much the better; if we don't make the 11,000 we can see what the shortfall is and whether we can find a creative solution.

Any questions, just ask.

Best regards
Jacek and Kira

Dr Kira Gee
Human Dimensions of Coastal Areas
Helmholtz Zentrum Geesthacht
Max-Planck-Str. 1, D-21502 Geesthacht

kira.gee@hzg.de

#07 Cormier, R., **2019**. Ecosystem approach for management of deep-sea mining activities, in: Sharma, R. (Ed.), Environmental Issues of Deep-Sea Mining: Impacts, Consequences and Policy Perspectives. Springer International Publishing.

Contribution to the field: This chapter introduces an ecosystem-based management operational approach deep-seabed mining. It demonstrates the use of risk management processes and tools in the analysis of the policy context and scope of UNCLOS for the development of regulatory frameworks for the deep-seabed mining. This chapter complements the regulatory work that the International Seabed Authority is currently undertaking.

This chapter is part of an initiative that was launch as a result of a workshop organized by the Institute for Advanced Sustainability Studies and the German Department of the Environment in collaboration with the UN International Seabed Authority.

To: roland.cormier@hzg.de

From: Sharma Rahul
Sent by: rsharma@nio.org
Date: 11/09/2017 07:50AM

Subject: Invitation to contribute a chapter in a book on 'Environmental issues of deep-sea mining'

(See attached file: Author acceptance form for contributors to the book on.docx)

(See attached file: Flyer-Deep-Sea Mining Sharma (Ed).pdf)

Dear Dr. Roland,

Greetings. This is Rahul Sharma Project Leader of EIA studies for Deep-sea Mining in Indian Ocean from National Institute of Oceanography and editor of the book on 'Deep-sea Mining' published by Springer in April 2017. I had an opportunity to listen to an excellent talk by you during the Berlin conference Environmental Management Strategy in March 2017.

This mail comes to you with a proposal to put together a book on 'Environmental issues of Deep-sea mining - key issues, impact assessment, environmental management, regulations'. This will be a sequel to the book published recently on 'Deep-sea mining – resource potential, technical and environmental issues' (flyer attached) with an emphasis on 'Environmental issues' in view of the ongoing discussions on Environmental Management Strategy, development of standards, EIS and EMPs.

Tentatively, the chapters would be distributed under the following sections.

A. Environmental issues of deep-sea mining
B. Assessment of potential impacts
C. C. Data management and environmental standards
D. Development of EIS, EMP
E. Regulations for environmental management

As one of the leading experts in this field, I invite you to contribute a chapter on one of the issues related to the above mentioned areas. A suggested topic for your chapter could be 'Ecosystem approach for management of deep-sea mining'. However, I urge you to suggest a suitable title and involve any of your colleagues or subject experts as your co-authors.

To begin with, I propose to suggest 31 March 2018 as the initial deadline for the chapters, which could be extended later on. I am certain that your chapter will contribute immensely towards addressing the environmental issues of deep-sea mining and hope that you would accept the invitation. I request you to give your acceptance in the attached form to proceed further with the publisher.

I look forward to a positive response from you and your contribution in this endeavor.

With best wishes.

Dr. Rahul Sharma
Chief Scientist
National Institute of Oceanography
Goa, India
Phone: +91-832-2450362
Mobile: +91-9422438077
Email: rsharma@nio.org, rsharmagoa@gmail.com