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Marine and coastal ecosystem-based risk management handbook

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Foreword

The management of environmental issues is usually linked to chains of cause and effect. In the widely used DPSIR Framework (Driving forces, Pressures, State, Impacts, Responses), they are analytically structured along pressures, which are caused by one or multiple drivers and resulting changes in the state of the ecosystem or ecosystem components. These changes may lead to impacts on the societal use of ecosystem goods and services and require responses in the form of specific management actions, which can be regulatory, that is, based on market incentives and/or any rules agreed among the major stakeholders. In most cases, environmental management responses are designed to eliminate, control, mitigate, or compensate pressures related to the drivers of human activities with the purpose of avoiding potential environmental effects. They often aim at a specific quantitative level of pressures, for example reaching a particular regulatory set threshold for a specific pollutant.

Measures in environmental and spatial planning are rarely formulated specifically in terms of risk management, with the intention of avoiding or mitigating particular impacts to ecosystem components or ecosystem goods and services. However, the concept of risk is well known in fields such as civil and mechanical engineering, food safety, and natural hazard management. Further, many decisions in environmental and spatial planning are based directly or indirectly on risk assessment. For example, in marine spatial planning in northern Europe, a key issue is the separation, with the help of particular zoning approaches, of shipping from offshore wind-farm installations in order to avoid the risk of accidents and oil spills.

Within the ICES Working Group on Marine Planning and Coastal Zone Management (WGMPCZM) and its predecessor, the Working Group on Integrated Coastal Zone Management (WGICZM), aspects of risk analysis and risk management have been introduced and discussed since 2007. This report is a handbook based on these discussions. It aims to connect the risk management framework of ISO (International Organization for Standardization) 31000 with concepts of environmental assessment, integrated coastal zone management (ICZM), and marine spatial planning (MSP). The report interprets components of coastal and marine environmental and spatial planning in the context of the rigid risk management structures and terminology of ISO. However, the report does not aim to discuss planning approaches in terms of their advantages and disadvantages or to discuss alternative forms of analysis and assessment. Its style is more like a normative text as produced by a standards organization. Mainly, the report provides guidance on how to apply the various concepts of environmental and spatial assessment and planning in a risk management structure. Owing to this, it can be seen as a contribution that might be interesting for policy-makers working at different levels and scales, scientific advisors and researchers in the field of applied marine and coastal sciences.

—Andreas Kannen, Chair

ICES Working Group on Marine Planning and Coastal Zone Management

1 Introduction

Management of any environmental issue requires the application of management measures designed to eliminate, control, mitigate, or compensate for pressures related to the drivers of human activities to avoid potential environmental effects. Management strategies are typically implemented in the form of regulations, policies, programmes, best management practices, standard operating procedures, management targets, and even stewardship and education, to name a few. In practice, environmental management measures target driver-specific pressures to reduce the risk of environmental effects and subsequent impacts on vulnerable ecosystems and environmental services. Particularly in the marine environment, the coastal zone is influenced by many drivers occurring within a very dynamic ecosystem, integrating land-based and marine influences. Already managed by a complex jurisdictional framework, each of these pressures can cause environmental effects individually or in combination with pressures from other drivers. From a simple management perspective, the challenge lies in identifying environmental management priorities that consider the most significant pressures and ecosystem vulnerabilities.

Risk analysis and management are widely used in various management constructs from civil and mechanical engineering to food safety and human health. The World Trade Organization (WTO) has embedded risk analysis in the Agreement on the Application of Sanitary and Phytosanitary Measures, which considers the protection of human, animal, and plant health in products traded internationally. Among the types of risk analysis and management approaches studied, some are based on probabilistic models and others are more qualitative in nature.

The International Organization for Standardization (ISO) also published a standard on risk management and risk assessment techniques. In this standard, the management of risks is based on identifying clearly the sources of these risks, analysing their consequences, and evaluating management options. Under the lead of a competent authority, the process includes communication and consultation with affected stakeholders as well as review and monitoring. In environmental management, the application of such risk management approaches provides assurance that management measures adequately protect the sustainability of the most vulnerable ecosystems and environmental services. Such a process not only assesses ecosystem risks, but aims to implement management measures and deploy resources to priorities of the highest ecosystem, social, cultural, economic, and policy risks. A key benefit of risk management frameworks and processes is also the identification and implementation of the most effective and efficient management measures based on existing scientific knowledge, legislation, and technologies.

In this handbook, the ISO 31000 standard for risk management and risk assessment techniques is used as the basis for an ecosystem-based, risk management approach. Considered as "events", environmental effects are at the centre of this process, where the consequences can alter, disrupt, or even degrade ecosystems.

This document bridges the ISO 31000 risk management framework with the ecosystem-based management approach used in environmental assessment, integrated coastal and oceans management, and marine spatial planning. Given the generic content of this framework, the intent of this document is to provide basic project planning blocks for any ecosystem-based management project.

The document does not debate the pros and cons of various practices extensively. It is written in the style of a normative text produced by organizations such as the United Nations or other standards organizations. Each step of this ecosystem-based, risk management framework refers to the relevant ISO sections or definitions as well as documents by other organizations such as the Organisation for Economic Co-operation and Development (OECD). Key references, further reading, and quality assurance checklists are also provided. Figure 1.1 provides definitions of the pictograms used in this document. It should be noted that the Driving forces-Pressures-State-Impacts-Responses (DPSIR) definitions are used throughout this report. Finally, the first four sections introduce the concepts of risk management, ecosystem management, and definitions, setting the stage for the process diagrams that follow.

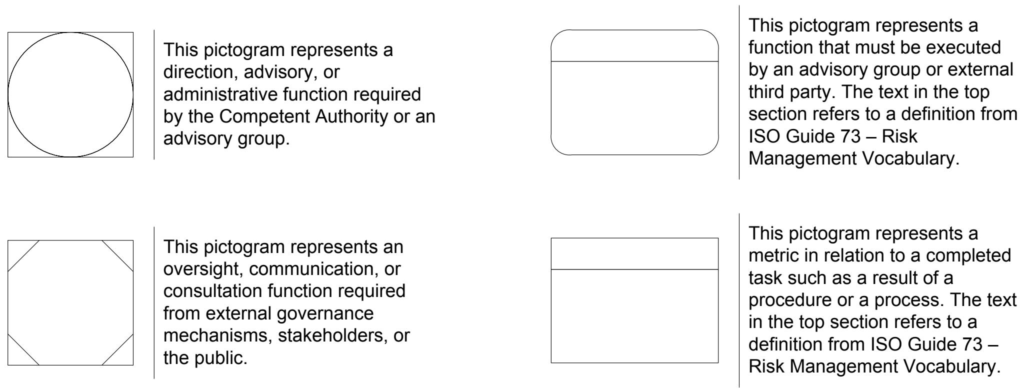

Figure 1.1. Definitions for the pictograms used in this report.

2 Risk management and risk analysis approaches

Risk analysis and management approaches are used in a variety of management regimes covering such areas as engineering, business, and human health and safety. Countries and international organizations have developed a variety of models. From the context of ecosystem-based management (EBM), development coupled with natural variations in ecosystem processes introduces uncertainties about ecosystem sustainability objectives. Using an ecosystem-based risk management (EBRM) approach, ecosystem risks are managed by identifying, analysing, and evaluating environmental factors to determine if management strategies are meeting pre-set ecosystem management risk criteria. The World Trade Organization (WTO) developed a risk analysis approach with the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) in 1995. Lately, environmental risk management frameworks have been developed using the ISO 31000:2009 Risk Management Standard.

World Trade Organization

Under the SPS Agreement, the WTO risk analysis approach is a requirement when establishing management measures to ensure human, plant, and animal health. WTO risk analysis is a systematic way to gather, evaluate, record, and disseminate information, leading to recommendations for a position or action in response to an identified hazard. Risk analysis consists of:

- **hazard identification**, which specifies the adverse event that is of concern;
- **risk assessmen**t, which takes into account the probability (the actual likelihood and not just the possibility) of the hazard occurring, the consequences of that hazard occurring, and the degree of uncertainty involved;
- **risk management**, which identifies and implements the best option for reducing or eliminating the likelihood of the hazard occurring;
- **risk communication**, which implies the open exchange of explanatory information and opinions leading to better understanding and decision-making.

Given the specificity of disciplines for conducting such analysis in such a wide array of fields, the WTO relies on three sister organizations to lead and develop risk analysis frameworks and standards.

- Codex Alimentarius Commission (CODEX) establishes international food safety and quality normative standards.
- World Organisation for Animal Health (OIE) establishes international animal health normative standards for the detection and reporting of diseases.
- International Plant Protection Convention (IPPC) establishes international plant protection normative standards for the detection and reporting of pests and non-indigenous species.

Further reading

Australia Standards. 2006. Handbook: Environmental risk management – Principles and process. HB 203:2006.

Food and Agriculture Organization. Multilateral Trade Negotiations on Agriculture – A Resource Manual/SPS and TBT Agreements. FAO Training Series, Part III. Document: X7354E.

Nunneri, C. 2007. Linking Ecological and Socio-economic Systems Analysis – A methodological approach based on Ecological Risk. Berichte aus dem Forschungs- und Technologiezentrum Westküste No. 45, Büsum 2007.

Sardá, R., Diedrich, A., Tintoré, J., Pablo Lozoya, J., Cormier, R., Hardy, M., and Ouellette, M. 2010. Decision making (DEMA) tool and demonstration. KnowSeas. Deliverable 6.2 Development of Risk Assessment. European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number 226675.

World Trade Organization. 1999. SPS Agreement Training Module. Available online at http://www.wto.org/english/tratop_e/sps_e/sps_agreement_cbt_e/signin_e.htm).

In this framework, risk management processes and definitions are drawn from the International Organization for Standardization (ISO) risk management standard.

Key references

ISO. 2009. Risk Management Principles and Guidelines. International Organization for Standardization. ISO 31000:2009(E).

ISO. 2009. Risk Management Vocabulary. International Organization for Standardization. ISO GUIDE 73:2009(E/F).

ISO. 2009. Risk Management – Risk Assessment Techniques. International Organization for Standardization. IEC/ISO 31010.

In the flow charts and descriptive text, relevant sections of the ISO normative text and definitions are referenced as a means of connecting key elements of the ISO 31000 standard to EBM practices, tools, and approaches. While using this handbook, the reader should have copies of the ISO documents as reference to the normative text and definitions.

In addition to principles (ISO 31000:2009, Section 3 Principles), the ISO 31000 risk management process identifies a series of steps and processes to structure and inform management decision-making. This formed the basis for the ecosystem-based, risk management framework of this report (Figure 2.1).

The ISO risk management process is subdivided into three main components: "Establishing the context", "Risk assessment", and "Risk treatment". It also includes two supporting functions, "Communication and consultation" and "Monitoring and review". In addition, "Risk assessment" is subdivided into "Risk identification", "Risk analysis", and "Risk evaluation".

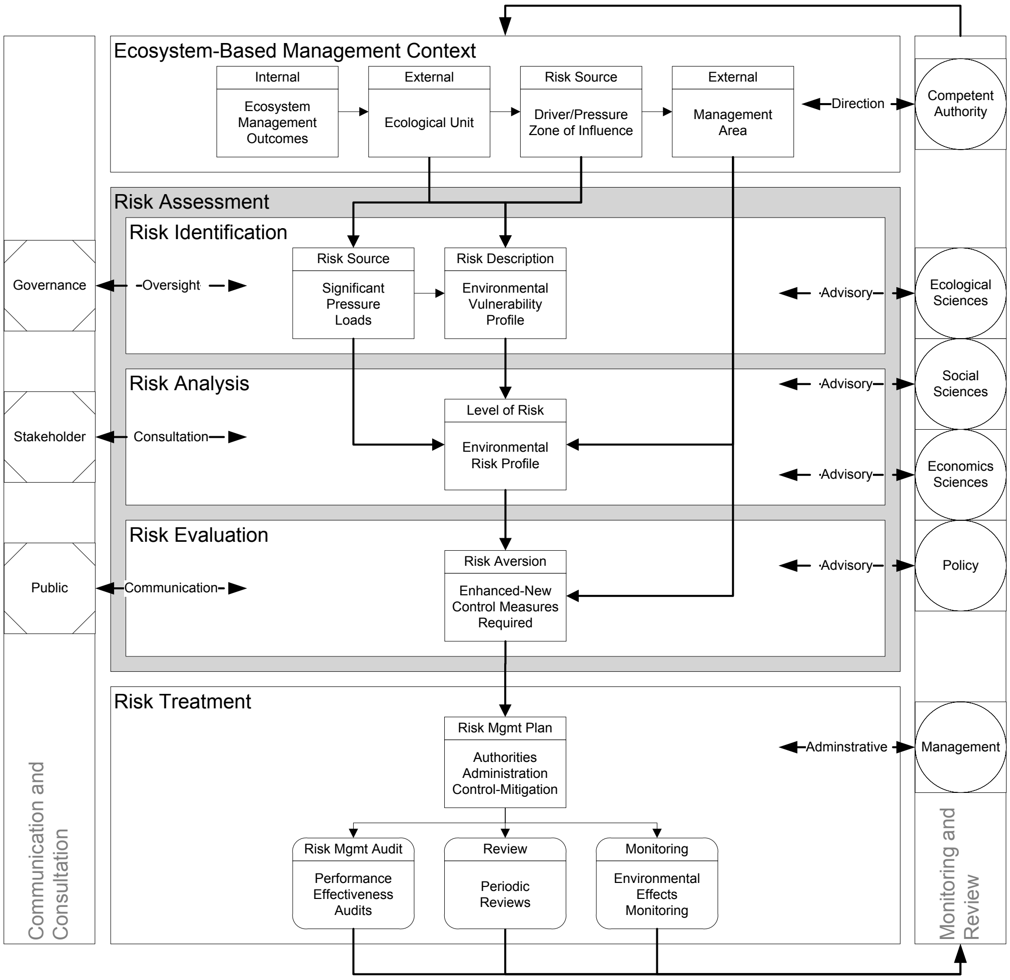

Figure 2.1. Ecosystem-based, risk management process (adapted from ISO 31000).

2.1 Ecosystem-based management context

(ISO 31010:2009 4.3.3: Establishing the context)

Within the context of ecosystem-based management practices, such as integrated management, marine spatial planning, or environmental assessments, the context of the risk management initiative needs to establish the ecological and management basis for managing risks as they relate to potential environmental effects. It also identifies the competent authority that will lead the process in terms of legislative, policy, and mandate related to sustainability and ecosystem management outcomes, as well as setting the risk criteria. The geographical boundaries of the ecosystem and zone of influence of the drivers are used to define the management area and the scope of the potential environmental effects to be assessed. The management area defines the type of governance structure required to address the multijurisdictional partnership management requirements as well as affected stakeholders and public policy communications. The external context is also considered in terms of key drivers and trends that affect the organization, as well as cultural, social, political, financial, technological, and economic factors that can affect the assessment, whereas the internal context includes the organizational capacities and culture (Figure 2.2).

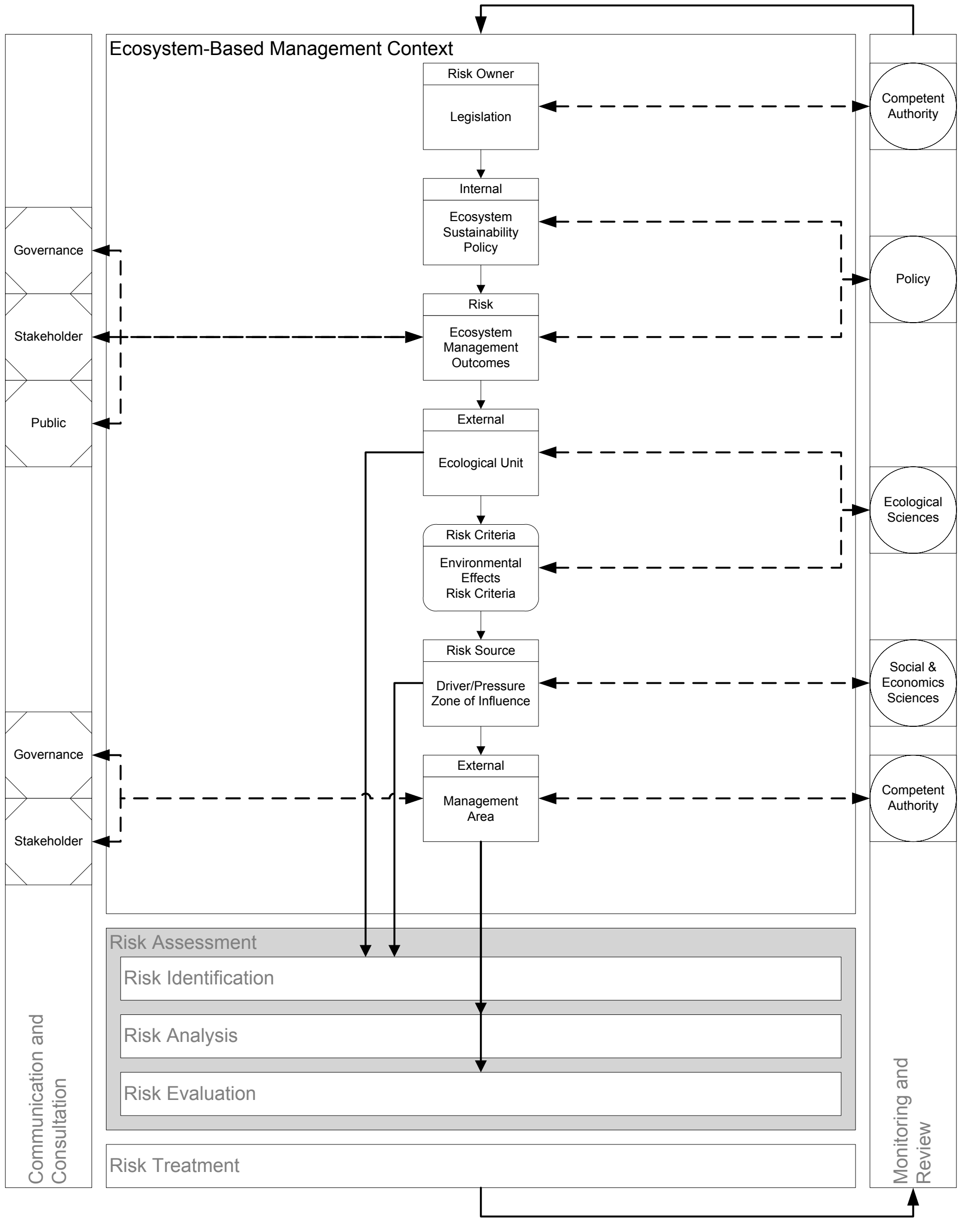

Figure 2.2. Ecosystem-based management contexts.

2.2 Risk assessment

(ISO 31010:2009 4.3.4: Risk assessment)

Risk assessment ascertains the likelihood and magnitude of an environmental effects event (ISO Guide 73: Event), based on the ecosystem vulnerabilities within the boundaries of the ecosystem and the zone of influence of the drivers. The assessment also identifies the consequences of not taking appropriate management action to avoid the effects in terms of ecological, social, cultural, and economic impacts as well as institutional policy and governance repercussions. The key output of risk assessment is the decision to either take or not take action based on the evaluation of existing control and mitigation strategies and the level of risk (ISO Guide 73: Level of risk) that the competent authority and stakeholders consider acceptable (ISO Guide 73: Risk acceptance). Risk assessment is subdivided into risk identification, risk analysis, and risk evaluation.

2.2.1 Risk identification

(ISO 31010:2009 5.2: Risk identification)

Risk identification (Figure 2.3) sets the ecosystem basis for the risk management process in terms of ecological vulnerabilities that support significant environmental services. Based on the ecosystem management outcomes, ecosystem environmental effects vulnerabilities are identified, taking into account the pressure loads of the drivers in the zone of influence where load is the product of intensity/severity, spatial extent, and temporal duration. The environmental vulnerabilities are then validated against stakeholder and public-risk perceptions in light of the data and knowledge collected. The key output of risk identification is an environmental vulnerability profile that is then used to prioritize the activities of the risk analysis.

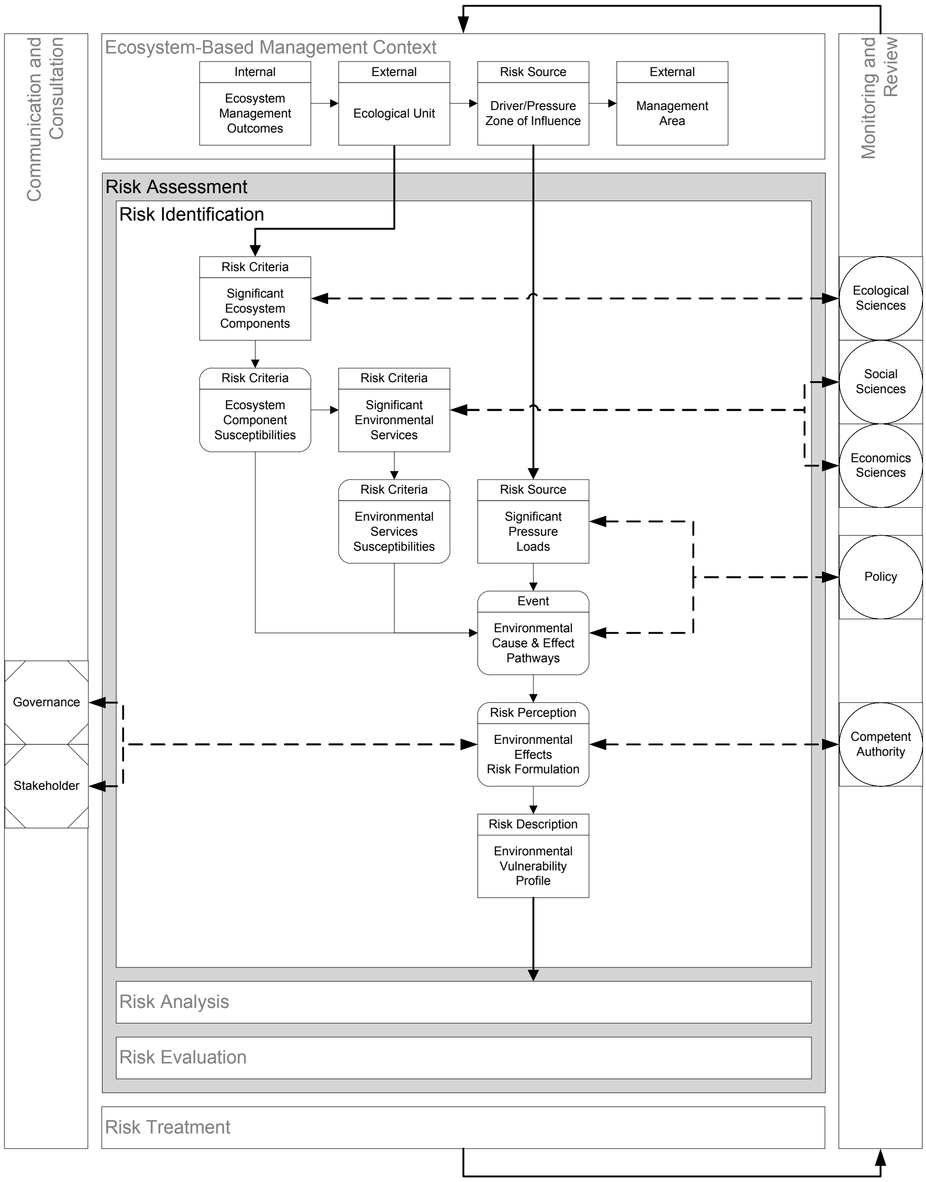

Figure 2.3. Risk identification.

2.2.2 Risk analysis

(ISO 31010:2009 5.3.1: Risk analysis)

Based on the environmental vulnerability profile, risk analysis (Figure 2.4) determines the likelihood of environmental effects and their respective ecosystem and environmental impacts, based on an analysis of existing control, mitigation, and compensation measures. Throughout this report, mitigation measures implemented after the occurrence of environmental effects include the compensation or offset of ecosystem losses, such as restocking of a resource, restoration of habitat, or even financial compensation to offset losses. This step of the risk assessment is very similar to most ecosystem assessments. The level of risk is determined via a gap analysis of control and mitigation measures identifying gaps or inconsistencies. This is done with an appreciation of the potential or predicted ecosystem, social, economic, and policy consequences. The output of risk analysis is an environmental risk profile that is then used to inform the risk evaluation to determine if and where management actions are required.

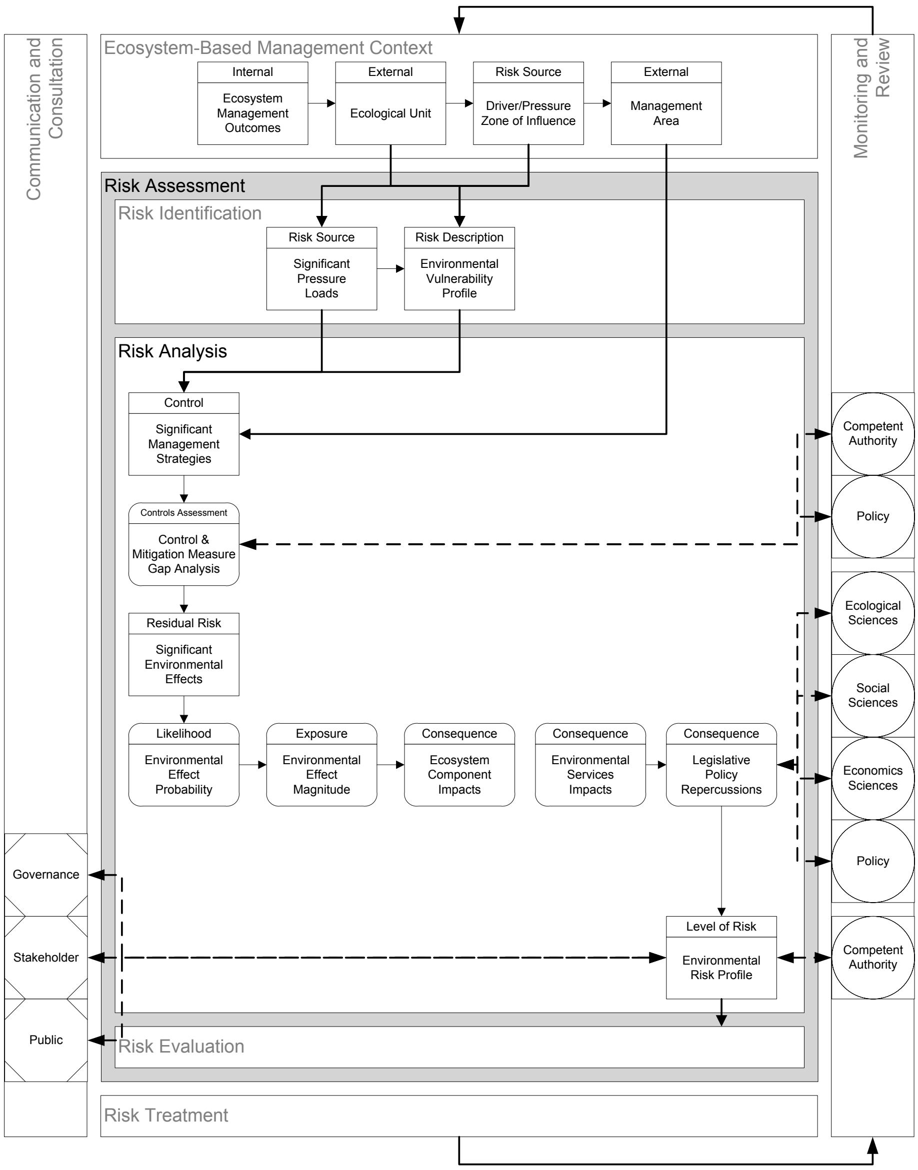

Figure 2.4. Risk analysis.

2.2.3 Risk evaluation

(ISO 31010: 2009 5.4: Risk evaluation)

Risk evaluation is a key decision step of risk assessment (Figure 2.5). Here, the competent authority has to make a decision regarding the need for management action in consultation with jurisdictional partners, stakeholders, and public policy direction in light of public perception. The environmental risk profile provides the most up-to-date knowledge of the risks of environmental effects, causes, and consequences, and plays a key role in informing the decision-making process (ISO Guide 73: Risk, risk source, consequence). Control and mitigation measure inconsistencies and gaps are assessed to determine if new or enhanced measures are required to reduce the risk of environmental effects to an acceptable level. The key output of the risk evaluation is a decision that (i) no new measures are needed, (ii) existing measures are adequate, or (iii) new or enhanced measures need to be implemented. In the first two cases, the process will not move to the "risk treatment" step; thus, terminating the risk assessment and moving the risk management activities to "review and monitoring", in terms of environmental effects monitoring and management performance audits of existing control and mitigation measures and processes. In the latter case, the risk management process identifies potential management options and moves to the risk treatment step to develop and implement new or enhanced management measures.

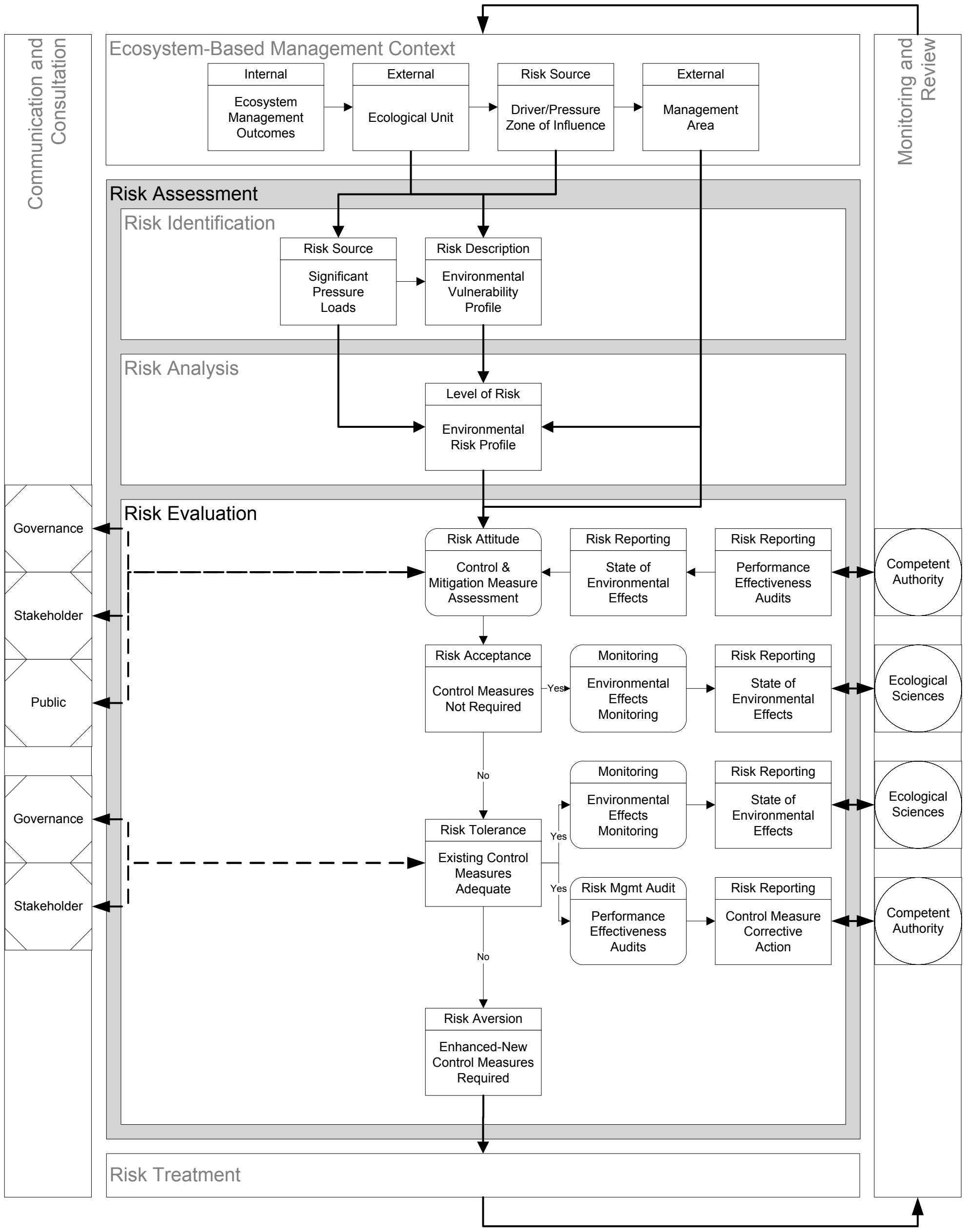

Figure 2.5. Risk evaluation.

2.3 Risk treatment

(ISO 31010:2009 4.3.5: Risk treatment)

Risk treatment is the development and implementation of new management strategies and measures designed to eliminate, control, or mitigate the risks of environmental effects (Figure 2.6). This step assesses the effectiveness and feasibility of the management options, including the cost and benefits of implementation. Once the management strategies and measures have been selected, a management plan is implemented by the management body responsible for its administration and operation. While in operation, the management body conducts performance and effectiveness audits, oversees environmental effects monitoring, and prepares reviews. These provide the basis for future adaptive management strategies in light of new ecosystem, social, cultural, or economic knowledge, as well as new management technologies and trends in the development of drivers and their pressures.

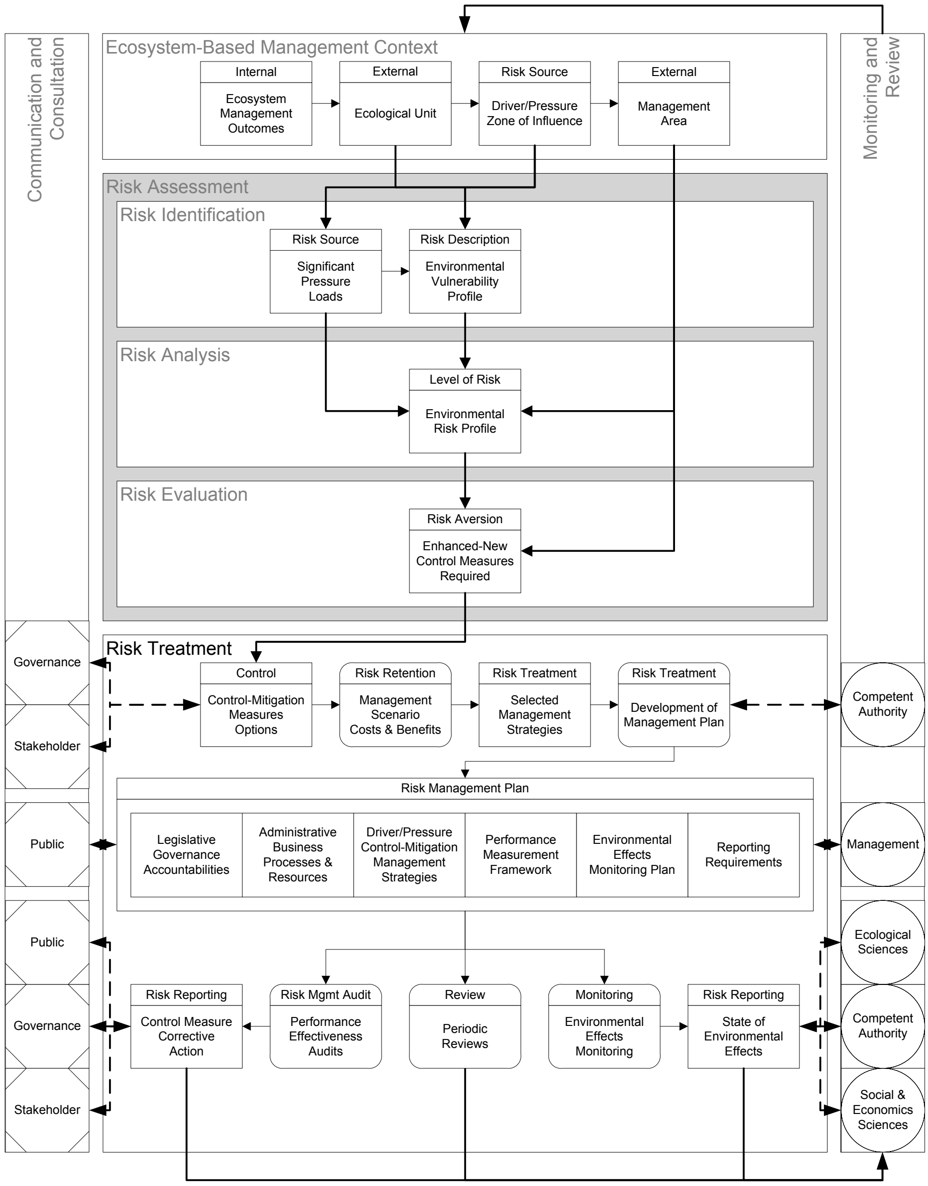

Figure 2.6. Risk treatment.

2.4 Risk communication

(ISO 31010:2009 4.3.2: Communication and consultation)

Risk communication is primarily the engagement and consultation function of the ecosystem-based, risk management process. Communication and consultation strategies (Figure 2.7) should be developed early in the planning stages of a risk management process. This function is a key quality assurance step ensuring that regulators, stakeholders, and the public are informed and consulted as the process moves forwards. It also assumes the function of information dissemination, ensuring transparency. It communicates the terms of reference defining decision-making authorities and management implementation accountabilities, including advisory roles and responsibilities. It takes into account the audience involving the scientific experts to ensure credibility of the sources and analysis of information. It differentiates between science-based facts and value judgments, and puts the risks into perspective to address the perceptions of risk. Once a management plan has been implemented, the reporting of performance and effectiveness audits and environmental effects monitoring results are an integral part of the risk communication and consultation function in terms of education and feedback mechanisms of adaptive management.

Figure 2.7. Risk communication and consultation.

2.5 Monitoring and review

(ISO 31010:2009 4.3.6: Monitoring and review)

Scientific and policy–advisory processes play a key review role in setting risk criteria, defining the ecological basis for management, and assessing the risks and management options. It also includes the functions of the competent authority and the operational aspects of managing the process and management plan implementation. Following the principles of adaptive management, performance and effectiveness audits and environmental effects monitoring are used to ascertain if the management plan is meeting ecosystem management objectives. An audit is a planned, independent, and documented evaluation to determine whether an agreed management plan and control or mitigation measures are being implemented. Coupled with environmental effects monitoring, it ascertains the effectiveness of the implementation as well as the performance of the institutions and processes in the administration of the plan. The monitoring can be separated into surveillance monitoring whereby the system is checked for irregularities, and compliance monitoring, whereby the operational body must report to the competent authority the results of the licence/authorization monitoring, followed by corrective action.

When non-conformities related to a specific management measure are continuously found, the risk management measures and strategies may need a complete review. In some cases, the risk assessment statistical assumptions and methods may also need to be reviewed to ensure the success of remedial action.

3 Ecosystem-based management

There are different definitions, approaches, and principles of ecosystem-based management (EBM) that are embodied in a broad range of environmental planning and management activities, including integrated coastal and oceans management, marine spatial planning, and strategic and regional environmental assessments, to name a few. Although authors and institutions have published a variety of EBM documentation, the UNEP guide (2011) is used to define EBM for this risk management framework.

Key reference

UNEP. 2011. Taking Steps toward Marine and Coastal Ecosystem-Based Management – An Introductory Guide. UNEP Regional Seas Reports and Studies No. 189. 68 pp.

Similar to the principles found in ISO risk management principles, UNEP considers five core elements of EBM, which have been adapted in this document:

- recognizing connections among marine, coastal, and terrestrial systems, as well as between ecosystems and human societies;
- using an ecosystem services perspective, where ecosystems are valued for the basic goods they generate (such as food or raw materials), as well as for the important services they provide (such as clean water and protection from extreme weather);
- addressing the cumulative impacts of various activities affecting an ecosystem;
- managing and balancing multiple and sometimes conflicting objectives that are related to different benefits and ecosystem services;
- embracing change, learning from experience, and adapting policies throughout the management process.

From these five core elements, UNEP provides a general description of the phases that should be undertaken for an EBM process.

Visioning phase. Establish a foundation for EBM:

- identify target geographical area and key concerns;
- build interest, expand participation, and create settings for sectors to come together;
- develop a common understanding of the ecosystem;
- take stock of existing management practices;
- set overarching goals.

Planning phase. Chart the EBM process:

- assess the ecosystem;
- evaluate EBM governance options and create legal frameworks to support multisectoral management;
- identify measurable objectives;
- prioritize threats, evaluate management options, and examine trade-offs; and
- choose management strategies for EBM implementation.

Implementation phase. Apply and adapt EBM:

- monitor, evaluate, and adapt;
- continue to communicate and educate;
- secure sustainable financing for EBM implementation.

In this framework, the key elements of the "Visioning phase" can be connected to the "Establishing the context" step of the ISO risk management process. The key elements of the "Planning phase" can be connected to the "Risk assessment" step, where ecosystem assessments and management options are identified for priority environmental effects. Finally, the key elements of the "Implementation phase" can be connected to the "Risk treatment", "Communication and consultation", and "Monitoring and review" steps, with a particular focus on environmental effects monitoring and performance audits of the implemented plan. Although connecting ISO and EBM approaches is not completely aligned, this UNEP document provides a practical guide to bringing together the two approaches. In both approaches, each step is inherently iterative as governance policy discussions, stakeholder consultations, and expert advice inform the risk management process.

Further reading

Ehler, C., and Douvere, F. 2007. Visions for a Sea Change. Report of the First International Workshop on Marine Spatial Planning. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 46, ICAM Dossier, 3. UNESCO, Paris.

Ehler, C., and Douvere, F. 2009. Marine Spatial Planning: A Step-by-Step Approach Toward Ecosystem-Based Management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. UNESCO, Paris.

Farmer, A., Mee, L., Langmead, O., Cooper, P., Kannen, A., Kershaw, P., and Cherrier, V. 2009. The Ecosystem Approach in Marine Management. EU FP 7 KNOWSEAS Project. ISBN 0952908956. Available online at http://www.knowseas.com/links-and-data/project-publications/D2_4_final.pdf/view.

ICES. 2005. Guidance on the Application of the Ecosystem Approach to Management of Human Activities in the European Marine Environment. ICES Cooperative Research Report No. 273. 22 pp.

UN. 2009. Training Manual: Ecosystem approaches to the management of ocean-related activities. United Nations Publication Sales No. E.10.V.11. 275 pp.

4 Ecosystem and environmental definitions

Because there is a wide variety of definitions and interpretations of terms used, it is imperative that, in preparing manuals such as this one and in conducting risk management processes, the terms and definitions used are based on national or international normative texts, where available. As mentioned earlier, risk management and assessment terminology is based on ISO normative text. From an ecological and environmental perspective, OECD and UN glossaries are used and expanded in this manual.

Key references

OECD. 2007. Glossary of statistical terms. Organization for Economic Co-operation and Development. Available online at http://stats.oecd.org/glossary/download.asp.

UN. 1997. Glossary of Environment Statistics. Studies in Methods, Series F, No. 67, United Nations, New York.

The following are selected terms from the above glossaries that are quoted and expanded on in this report.

Ecological amplitude. Ecological amplitudes are the limits of environmental conditions within which an organism can live and function.

Ecological approach to sustainable development. Economic and social systems are subsystems of the global environment; sustainability in the economic and social spheres is subordinate to sustainability of the environment. Development, from the ecological viewpoint, refers to the capacity of an ecosystem to respond positively to change and opportunity or the maintenance of ecosystems dynamic capacity to respond adaptively (Golley, 1990). The key property to be sustained is the capacity of ecosystems to respond with resilience to external perturbations and changes.

Ecological footprint. An ecological footprint is the land (and water) area of the planet or particular area required for the support either of humankind's current lifestyle or the consumption pattern of a particular population. It is the inverse of the carrying capacity of a territory.

Ecological impact. Ecological impact is the effect of human activities and natural events on living organisms and their non-living environment.

Economic benefits from environmental functions (SEEA). Direct-use benefits, indirect-use benefits, option benefits, bequest benefits, and existence benefits.

Economically significant prices. Prices are considered economically significant if they have a significant influence on the amounts producers are willing to supply and on the amounts purchasers wish to buy.

Ecoregion (Ecozone). An ecoregion is a homogeneous area of one or more ecosystems that interact with relatively self-contained human activities.

Ecosystem inputs. Ecosystem inputs cover the substances absorbed from the ecosystem for purposes of production and consumption, such as the gases needed for combustion and production processes as well as oxygen, carbon dioxide, water, and nutrients.

Ecosystem services. Ecosystem services cover the provision of ecosystem inputs, the assimilative capacity of the environment, and the provision of biodiversity.

Ecosystem. An ecosystem is a system in which the interaction between different organisms and their environment generates a cyclic interchange of materials and energy. Context: groups of organisms and the physical environment they inhabit. Three main types of ecosystem assets are recognized in the SEEA: terrestrial ecosystems, aquatic ecosystems, and atmospheric systems.

Environment. The environment is the totality of all of the external conditions affecting the life, development, and survival of an organism. Context: the naturally produced physical surroundings on which humanity is entirely dependent in all its activities. The various uses to which these surroundings are put for economic ends are called **environmental functions**.

Environmental activities. Activities which reduce or eliminate pressures on the environment and which aim at making more efficient use of natural resources.

Environmental debt. Environmental debt is the accumulation of past environmental impacts of natural resource depletion and environmental degradation owed to future generations. Context: unremedied degradation, which carries forwards to a future period.

Environmental degradation. Environmental degradation is the deterioration in environmental quality from ambient concentrations of pollutants and other activities and processes, such as improper land use and natural disasters.

Environmental effect. An environmental effect is the result of environmental impacts on human health and welfare. The term is also used synonymously with environmental impact.

Environmental functions. Functions provided by the environment corresponding to the various uses to which naturally produced physical surroundings are put for economic ends. Three types of environmental functions are distinguished: resource functions, sink functions, and service functions. Context: environmental functions refer to environmental services, including spatial functions, waste disposal, natural resource supply, and life support.

Environmental impact. Environmental impact is the direct effect of socio-economic activities and natural events on components of the environment.

Environmental indicator. An environmental indicator is a parameter, or a value derived from parameters, that points to, provides information about, and/or describes the state of the environment, and has a significance extending beyond that directly associated with any given parametric value. The term may encompass indicators of environmental pressures, conditions, and responses.

Environmental media. Environmental media are abiotic components of the natural environment, namely, air, water, and land.

Environmental protection. Environmental protection is any activity to maintain or restore the quality of environmental media by preventing the emission of pollutants or reducing the presence of polluting substances in environmental media. It may consist of (i) changes in the characteristics of goods and services, (ii) changes in consumption patterns, (iii) changes in production techniques, (iv) treatment or disposal of residuals in separate environmental protection facilities, (v) recycling, and (vi) prevention of degradation of the landscape and ecosystems.

Environmental quality standard. An environmental quality standard is a limit for environmental disturbances, particularly from ambient concentration of pollutants and wastes that determines the maximum allowable degradation of environmental media.

Environmental quality. Environmental quality is a state of environmental conditions in environmental media, expressed in terms of indicators or indices related to environmental quality standards.

Environmental services. Environmental services refer to qualitative functions of natural, non-produced assets of land, water, air (including related ecosystem), and their biota. There are three basic types of environmental services: (i) disposal services, which reflect the functions of the natural environment as an absorptive sink for residuals; (ii) productive services, which reflect the economic functions of providing natural resource inputs and space for production and consumption; and (iii) consumer or consumption services, which provide for physiological as well as recreational and related needs of human beings. Context: these services include the provision of raw materials and energy used to produce goods and services, the absorption of waste from human activities, and the basic roles in life support and the provision of other amenities, such as landscape.

Environmental theme. A specific environmental phenomena or concern: greenhouse effect, ozone layer depletion, acidification, eutrophication, etc. Various residuals are converted into theme equivalent using conversion factors.

Monitoring (environmental). Monitoring is the continuous or frequent standardized measurement and observation of the environment (air, water, land/soil, biota), often used for warning and control.

Sustainable development. Sustainable development refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). It assumes the conservation of natural assets for future growth and development.

Further reading

Atkins, J. P., Burdon, D., Elliott, M., and Gregory, A. J. 2011 Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin, 62(2): 215–226.

Elliott, M., Burdon, D., Hemingway, K. L., and Apitz, S. 2007. Estuarine, coastal, and marine ecosystem restoration: confusing management and science – a revision of concepts. Estuarine, Coastal and Shelf Science, 74: 349–366.

Golley, F. B. 1990. Love of the land. Landscape Ecology, 4: 81–82.

World Commission on Environment and Development (Brundtland Commission). 1987. Our Common Future. Oxford University Press, Oxford, UK.

5 Drivers (driving forces), pressures, state, impacts, responses (DPSIR)

Note that these indicators have been adapted or changed in recent years in relation to specific projects. To maintain consistency in the definitions of terms in this report, the UNEP DPSIR definitions are used throughout the document.

Key reference

UNEP/GRID-Arendal. 2002. DPSIR framework for state of environment reporting. Maps and Graphics Library. Available online at http://maps.grida.no/go/graphic/dpsir_framework_for_state_of_environment_reporting

DPSIR is a general framework for organizing and defining information about the state of the environment and the human uses of it. The framework is also used for organizing systems of indicators in the context of environmental health and sustainable development. In this ecosystem-based, risk management framework, DPSIR is used to identify cause-and-effect pathway relationships between interacting components of ecological, social, and economic systems with environmental effects events. The response (R) is used to identify where along the pathway a control or mitigation measure can be implemented to reduce the risks of environmental effects. The following elaborates on the definitions and their application in this framework.

Drivers (driving forces) are considered as the social, cultural, economic, and regulatory forces that drive human activities in the ecosystem and which place pressure on the environment, such as population, marine transportation, agricultural production, fisheries, and tourism.

Pressures are the number or load of physical, chemical, or biological products discharged or produced by the drivers, such as wastewater, sediment and fertilizer run-off, fish catches, or aggregate extraction.

State changes are the environmental effects of water quality in rivers, quality of eelgrass in estuaries, concentration of contaminants, fish stock status, coastal erosion, level of non-indigenous species invasion, and marine litter. Generally, the state of the environmental effects would establish the level of disruptions, alterations, or degradation in terms of contaminants, sediments, nutrients, or hydrographical regimes as well as habitat or biota integrity.

Impacts are related to the societal uses of ecosystem components and processes, and are considered equal to impacts on environmental services, such as social, cultural, and economic goods and services. Considered as effects of environmental degradation, examples may include algal blooms or macroalgae changes affecting human use, water-related human health problems, changes in species distribution and abundance affecting human use, flooding, seabed destruction, loss of habitat, and genetic disturbances with societal repercussions. Recent research initiatives (KnowSeas) have separated ecological impacts (I) from impacts to the human system; thus adding human welfare (W) to the framework.

Responses are the management measures implemented via regulations, policies, governance, economic instruments, best management practices, standards, and stewardship or education strategies. Developed and implemented to achieve ecosystem management objectives, these may have regional, national, or international applications. Furthermore, the anagram has been extended to DPSIRR to include recovery as the results of response actions.

Further reading

Atkins, J. P., Burdon, D., Elliott, M., and Gregory, A. J. 2011. Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin, 62(2): 215–226.

DEDUCE. 2002. Indicators Guidelines: To Adopt an Indicators-Based Approach to Evaluate Coastal Sustainable Development. DEDUCE Consortium. Available online at http://www.deduce.eu/PDF-NewsLetter/indicators_guidelines.pdf.

KnowSeas. 2011. Knowledge-based Sustainable Management for Europe's Seas. European Commission. Environment Theme of the 7th Framework Programme for Research and Technological Development.

OECD InterFutures Study Team. 1979. Mastering the Probable and Managing the Unpredictable. Organisation for Economic Co-operation and Development and International Energy Agency, Paris.

UNESCO. 2006. A Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management. IOC Manuals and Guides No. 46; ICAM Dossier, 2. UNESCO, Paris.

6 Ecosystem-based management context

(ISO Guide 73: Establishing the context)

The ecosystem-based, risk management context (Figure 2.2) is the initial point that sets the ecological and risk management basis as they relate to potential environmental effects. It identifies the competent authority (ISO Guide 73: Risk owner) in terms of legislative and policy accountability as they relate to achieving the ecosystem management outcomes (ISO Guide 73: Internal context). Based on the driver zone of influence, the management area also defines the type of governance structure required to address the multijurisdictional partnerships and management requirements, including affected stakeholders and public-policy communications (ISO Guide 73: External context). At the stage of the initiative, the risk management process also has to be defined, including risk criteria, project plans, and deliverables (ISO 31010:2009 5.3.4: Establishing the context of the risk management process).

Quality assurance checklist

- What are the accountabilities, reporting structures, and decision-making points?
- What are the terms of reference for each of the governing, secretariat, and advisory bodies operating within this risk management process?
- What are the communication, engagement, and consultation procedures and reporting requirements?
- What are the peer-review processes for each technical advisory body?
- What are the sources of environmental effects data, indicators, criteria, and data collection standards?
- What are the information management processes and procedures for reports, minutes, decisions, and advice?

6.1 Legislation

(ISO Guide 73: Risk owner)

Based on the organization or body that has been designated by legislation or by an agreement, a competent authority is a person within the organization who has the legally delegated authority to set ecosystem sustainability policies and outcomes as well as lead or facilitate the ecosystem-based, risk management process. Legislation may authorize an organization to establish preventive controls in the form of best management practices, standard operating procedures, regulations, or management targets, or to establish mitigation controls in the form of environmental quality standards, spatial planning, and integrated management or sustainability objectives. The legislation may also authorize the competent authority to facilitate or lead the development of such strategies in collaboration with other authorities and stakeholders as well as issue authorizations in the form of consents, permits, or licences. The competent authority also has the authority to oversee the development and implementation of management strategies and report on their implementation in collaboration with other authorities and stakeholders, and the monitoring of environmental effects. In some cases, the competent authority may require the developer to implement environmental monitoring in relation to his or her development project. The legislation also sets the boundaries of the organization's ecosystem sustainability policies and programmes, which provides direction as to the ecosystem management outcomes.

Further reading

Canada. 1996. Oceans Act. Government of Canada. Available online at http://laws-lois.justice.gc.ca/eng/acts/O-2.4/page-1.html.

EU. 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, 25.6.2008. L 164/19.

Quality assurance checklist

- What are the legislative instruments under which the competent authority is accountable to implement an ecosystem-based management approach?

6.2 Ecosystem sustainability policy

(ISO Guide 73: Internal)

Based on a mandate of the competent authority, strategic policy objectives or overarching goals are the key to properly setting the scope of such a risk management exercise. In ecosystem-based management, overarching goals are often expressed in terms of sustainable development (OECD: Sustainable development), protection, or conservation objectives set at the ecosystem level (OECD: Ecological approach to sustainable development). Such overarching goals are then used to establish ecosystem management outcomes that subsequently frame the environmental effects risk criteria (ISO Guide 73: Risk criteria) and the needed management strategies to avoid the effects (OECD: Environmental protection). Often the sustainability policy is derived at the level of a national body that has some control over the successive competent authorities.

Further reading

Canada. 2002. Canada's Oceans Strategy: Our Oceans, Our Future Oceans Act. Fisheries and Oceans Canada, Oceans Directorate, Ottawa. 36 pp.

DFO. 2007. Guidance Document on Identifying Conservation Priorities and Phrasing Conservation Objectives for Large Ocean Management Areas. DFO Canadian Science Advisory Secretariat, Science Advisory Report, 2007/010.

EU. 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Union, L164/19.

US Council on Environmental Quality. 2010. Final recommendations of the Interagency Ocean Policy Task Force, July 19, 2010. 96 pp.

Quality assurance checklist

- What are the policy objectives as they pertain to an ecosystem-based management approach?

6.3 Ecosystem management outcomes

(ISO Guide 73: Risk)

As part of the visioning phase that establishes the foundation for ecosystem-based management (UNEP 2011), ecosystem management outcomes describe the expected results of existing or future implemented management strategies (OECD: Environmental quality). The outcomes set the stage for the types of environmental effects to be avoided and the implicated drivers or pressures that need to be managed. Outcomes are developed in consultation with external partners and stakeholders to reflect values and risk perceptions (ISO Guide 73: Risk perception). The wording should provide the basis for framing the risk criteria (ISO Guide 73: Risk criteria) and the indicators (OECD: Environmental indicator) to determine if the management strategies are achieving their respective outcomes. These should follow the SMART objectives being specific, measurable, achievable, realistic, and time-bounded.

The European Union good environmental status (GES) criteria can be used as an example of a comprehensive list of outcomes that are based on 11 interlinked descriptors covering the functioning of the system.

Key reference

EU. 2010. Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters [notified under document C(2010) 5956] (Text with EEA relevance 2010/477/EU). Official Journal of the European Union, L 232/14.

Ecosystem management outcomes are the starting point for developing environmental effects risk criteria and management strategies. The EU GES descriptors can be used as the endpoint of multiple cause-and-effect pathways connecting drivers to their pressures, their environmental effects, and subsequent ecosystem impacts to the GES. The integrative descriptors relate to trophic pathways, biodiversity, and seabed integrity, whereas other descriptors relate to individual pressures such as litter or noise. The following are the 11 descriptors of the GES.

Descriptor 1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographical, and climate conditions.

Descriptor 2. Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

Descriptor 3. Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

Descriptor 4. All elements of the marine foodwebs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

Descriptor 5. Human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms, and oxygen deficiency in bottom waters.

Descriptor 6. Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

Descriptor 7. Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

Descriptor 8. Concentrations of contaminants are at levels not giving rise to pollution effects.

Descriptor 9. Contaminants in fish and other seafood for human consumption do not exceed levels established by community legislation or other relevant standards.

Descriptor 10. Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

Descriptor 11. Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Further reading

Borja, Á., Elliott, M., Carstensen, J., Heiskanen, A-S., and van de Bund, W. 2010. Marine management – towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Marine Pollution Bulletin, 60: 2175–2186.

US EPA. 2001. Planning for Ecological Risk Assessment: Developing Management Objectives. EPA/630/R-01/001A. 87 pp. Available online at http://cfpub.epa.gov/ncea/raf/pdfs/eco_objectives-sab_6-01.pdf.

Quality assurance checklist

- What are the ecosystem management outcomes that are linked to the policy objectives?
- Who within the organization has the authority to approve the ecosystem management outcomes?

6.4 Ecological unit

(ISO Guide 73: External)

The ecological unit sets the ecosystem geographical boundaries for the risk management initiative. The ecological unit is also the ecological basis for identifying inherent ecosystem vulnerabilities (OECD: Ecological amplitude) and in defining the environmental effects risk criteria (OECD: Environmental effect, ISO Guide 73: Risk criteria). The ecological unit should be identified along ecological criteria that includes the physical (OECD: Environmental media), chemical, and biological components and processes occurring in a given space and time (OECD: Ecosystem, OECD: Environment). In this framework, the ecological unit defines the scale of the risk management initiative (OECD: Ecological footprint). It can be at a localized scale, such as a lake or river, or a very large scale, such as an estuary, coastal zone, or ocean.

Further reading

DFO. 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Canadian Science Advisory Secretariat, Science Advisory Report, 2009/056.

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Halpern, B. S., *et al*. 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. Bioscience, 57(7): 573–583.

UNESCO. 2009. Global Open Oceans and Deep Seabed (GOODS) – Biogeographic Classification. UNESCO–IOC Technical Series, 84, Paris. 89 pp.

Wilkinson, T., Wiken, E., Bezaury-Creel, J., Hourigan, T., Agardy, T., Herrmann, H., *et al*. 2009. Marine Ecoregions of North America. Commission for Environmental Cooperation. Montreal, Canada. 200 pp.

Quality assurance checklist

- What criteria and classification system have been used to establish the ecological unit and its boundaries?

6.5 Environmental effects risk criteria

(ISO Guide 73: Risk criteria)

Environmental effects (OECD: Environmental effect) are events directly caused by pressures released by drivers of human activities that change the quality of the environment (OECD: Environmental quality) in providing valued services (OECD: Environmental services). Risks may also be related to naturally occurring events, such as tsunamis or earthquakes, where risk management focuses on mitigation, restoration, and adaptive measures. Such events can have multiple impacts at the ecosystem level (OECD: Ecological impact) or the environmental level (OECD: Environmental impact) in terms of social, cultural, economic, and policy repercussions.

Based on the ecosystem management outcomes, ecological susceptibilities (OECD: Ecological amplitude) to specific environmental effects are identified within the boundaries of the ecological unit. Linked directly to specific pressures, the risk criteria are expressed in terms of the potential changes in the event that an environmental effect manifests itself (OECD: Environmental theme). These may be expressed in terms of the level of disruption, alteration, or degradation at the ecosystem services level (OECD: Ecosystem services). A disruption would be considered a short-term perturbation of limited spatial scale, where the environmental effect would dissipate upon the implementation of control or mitigation measures of the pressure. An alteration would be considered as a change in the habitat and biodiversity configurations, where the environmental effect may or may not restore itself from a habitat or biota perspective once control or mitigation measures are implemented. Degradation would be permanent loss of ecological functions and environmental services. In all cases, ecosystem functions or environmental services may be affected.

The following are a few examples:

- The introduction of contaminants, sediments, or nutrients may degrade the ecosystem to the point where components are lost or services capacities are surpassed.
- The introduction of noise may disrupt the water column habitat, hampering marine mammals.
- Trawling or dragging of the seabed may disrupt the benthic habitat from a structural perspective.
- The installation of permanent structures on the seabed may alter the benthic habitat in terms of surface-area productivity.
- The introduction of non-indigenous species may alter the biota in terms of biodiversity composition.
- The removal of biomass may disrupt the biota in terms of life cycle or trophic productivity.

It should be noted that, whereas some of these causes of disruption operate inside the system being managed (the endogenic managed pressures), others operate outside the system (exogenic unmanaged pressures). The risk criteria also classify and rank the risks in terms of the potential consequences or repercussions. These express potential losses in terms of ecosystem components and environmental services as well as regulatory and policy repercussions. The criteria also reflect the values of the regulators, stakeholders, and public describing the severity of an environmental effect event, such as being minor, significant, major, or catastrophic. The following are a few examples.

- A habitat disruption may affect an individual of a given species, whereas a habitat alteration may affect the population of a given species or the populations of several species.
- A biotic disruption in terms of temporary loss of productivity may affect an individual, whereas a biota alteration that changes the biodiversity may affect a community or an entire sector of the industry that depends on that resource.
- The repercussion of ecosystem degradation may be manageable with existing technologies and programmes or may require additional resources or the implementation of a multi-agency management strategy and new legislation.

The risk criteria are used as a benchmark throughout the entire risk management process. As an example, Fisheries and Oceans Canada (DFO) recently defined alteration, disruption, and destruction.

Key reference

DFO. 2012. Definitions of harmful alteration, disruption or destruction (HADD) of habitat provided by eelgrass (*Zostera marina*). DFO Canadian Science Advisory Secretariat, Science Advisory Report, 2011/058.

The definition reflects legislation requirements (e.g. with respect to fish and fish habitat.

- **Disruption**. Any change to fish habitat occurring for a limited period that reduces its capacity to support one or more life processes of fish.
- **Harmful alteration**. Any change to fish habitat that reduces its long-term capacity to support one or more life processes of fish, but does not permanently eliminate the habitat.
- **Destruction**. Any permanent change of fish habitat that renders it completely unsuitable for future production of fish, regardless of the means employed in causing the change (e.g. by removal, infilling, blockage).

The European Environment Agency (EAA) has developed a comprehensive series of questions that guide the reader in preparing a rationale for identifying significant environmental effects.

Key reference

EU EEA. 2000. Questions to be answered by a state-of-the-environment report: the first list. Technical Report, 47. 116 pp.

EEA style questions can facilitate the development of environmental effects risk criteria. Such questions should be asked in relation to the ecosystem management outcomes. The EEA broadly starts with the following questions.

- What is happening? (S)tate change, (I)mpact
- Why is it happening? (D)riving force, (P)ressure
- Are we seeing changes? (P)ressure, (D)riving force
- How effective are the responses? (R)esponse

Further reading

BMT. 2007. Research Project 591 Environmental Risk Criteria. 50012/D0137/Issue 2. December 2007. Unclassified.

Cardoso, A. C., Cochrane, S., Doerner, H., Ferreira, J. G., Galgani, F., Hagebro, C., Hanke, G., *et al*. 2010. Scientific Support to the European Commission on the Marine Strategy Framework Directive – Management Group Report. Office for Official Publications of the European Communities, Luxembourg. EUR – Scientific and Technical Research series. 57 pp.

EC. 2002. TAB #17: Risk Management for Contaminated Sites-Framework. Technical Assistance Bulletin, 17. Available online at http://www.on.ec.gc.ca/pollution/ecnpd/tabs/tab17-e.html.

HELCOM/VASAB, OSPAR, and ICES. 2012. Report of the Joint HELCOM/VASAB, OSPAR, and ICES Workshop on Multi-Disciplinary Case Studies of MSP (WKMCMSP), 2–4 November 2011, Lisbon, Portugal. 46 pp.

Quality assurance checklist

- What criteria and classification system was used to define the environmental effects in relation to the ecosystem management outcomes?
- What are the environmental effects that are linked to the ecosystem management outcomes?

6.6 Driver/pressure zone of influence

(ISO Guide 73: Risk source)

The zone of influence (OECD: Ecoregion) encompasses the area that includes the drivers and their pressures that can significantly contribute to the risks of environmental effects (OECD: Ecological footprint). The zone of influence may be at a larger scale than the ecological unit, such as a catchments basin, where drivers may influence the environmental quality of an estuary. It can be at a smaller scale inside the ecological unit, such as maritime traffic lanes in a bay creating a vulnerability to marine mammals. The zone of influence establishes the scope of the sources of risk that will be considered for the risk management initiative and the management area in terms of jurisdictions. In some contexts, these aspects are identified as near-field and far-field responses.

Quality assurance checklist

- What drivers and pressures can generate the identified environmental effects?
- What is the geographical distribution of the drivers and the zone of influence of the pressures?

6.7 Management area

(ISO Guide 73: External)

The management area groups the management jurisdictions, drivers, and stakeholders that are implicated in the management of drivers and pressures for achieving the ecosystem management outcomes of the ecological unit (OECD: Environmental protection). For example, they may be aligned with exclusive economic zones, territorial seas, or international, national, and regional collaborative management areas. The area should include the jurisdictions and drivers that fall within the zone of influence related to the environmental effects to be avoided. This can also imply the need for cooperation across borders, for example, between two or more countries.

Further reading

Canada. 2005. Canada's Oceans Action Plan for Present and Future Generations. Fisheries and Oceans Canada Ottawa. DFO/2005-348. 20 pp.

Gee, K., Kannen, A., and Heinrichs, B. 2011. BaltSeaPlan Vision 2030 for Baltic Sea Space. Hamburg, autumn 2011. Available online at http://www.baltseaplan.eu/index.php/BaltSeaPlan-Vision-2030;494/1.

Swaney, D. P., Humborg, C., Emeis, K., Kannen, A., Silvert, W., Tett, P., Pastres, R., *et al*. 2011. Five critical questions of scale for the coastal zone. Estuarine, Coastal and Shelf Science, 96: 9–21.

US CEQ. 2009. Interim Framework for Effective Coastal and Marine Spatial Planning Interagency Ocean Policy Task Force December 9, 2009. 32 pp.

UNEP/MAP/PAPRAC. 2008. Protocol on integrated coastal-zone management in the Mediterranean.

Quality assurance checklist

- Which organizations have legislations, policies, or programmes that complement the competent authority mandate in managing drivers within the management area?
- Who are the stakeholders of the drivers that will be managed in the management area?
- What agreements are in effect in the management area that can facilitate the achievement of ecosystem management outcomes?

7 Risk assessment

(ISO Guide 73: Risk assessment)

Risk assessment characterizes the likelihood of an environmental effect event, the severity of the ecological, social, cultural, and economic impacts, and the legislative and policy implications (OECD: Ecological impact, environmental impact). Risk assessment is key to informing management of the need to implement management strategies and measures. Risk assessment does not make the decision, but sets the risks within the context of potential consequences and management options for consideration. It should be noted that the risk context does not simply rely on predictive scenario modelling. Such modelling provides input data into risk criteria that are used to establish the risk profile and evaluate the management options. It should be noted that the environmental effects risk criteria must be established prior to the risk assessment while establishing the context of the risk management initiative.

Further reading

Bastien-Daigle, S., Hardy, M., and Robichaud, G. 2007. Habitat management quality risk assessment: water column oyster aquaculture in New Brunswick. Canadian Technical Report of Fisheries and Aquatic Sciences, 2728. 72 pp.

DFO. 2005. Guidelines on Evaluating Ecosystem Overviews and Assessments: Necessary Documentation. DFO Canadian Science Advisory Secretariat, Science Advisory Report, 2005/026.

Fletcher, W. J. 2005. The application of qualitative risk assessment methodology to prioritize issues for fishery management. ICES Journal of Marine Science, 62: 1576–1587.

Hobday, A. 2007. Including a Risk-Based Component in the MSC Certification Process: a Solution for Data-Deficient and Small-Scale Fisheries Assessments. Guidance document for the Marine Stewardship Council. London, UK. 57 pp.

OECD. 2006. Applying Strategic Environmental Assessment: Good Practice Guidance for Development Co-operation. DAC Guidelines and Reference Series. 162 pp.

Scheltinga, D. M., and Moss, A. 2007. A framework for assessing the health of coastal waters: a trial of the national set of estuarine, coastal and marine indicators in Queensland, Environmental Protection Agency Queensland, prepared for the National Land and Water Resources Audit, Canberra.

7.1 Risk identification

(ISO Guide 73: Risk identification)

Each step of risk identification is based on the elements identified in the ecosystem-based management context. In risk identification, the significant ecosystem and environmental components are based on the ecological unit. The significant pressure loads and environmental cause-and-effect pathways are based on the environmental effects risk criteria and the drivers that are found in the zone of influence. Risk formulation is, in part, a priority-setting exercise in relation to the environmental effects of concern in light of the ecosystem management outcomes.

7.1.1 Significant ecosystem components

(ISO Guide 73: Risk criteria)

Significant ecosystem components (OECD: Ecosystem) are species, habitat features, community properties, or ecosystem processes that provide ecological functions within the ecological unit. Although all species and habitat features in a given area have some ecological function, significant ecosystem components are considered to be the components where a change caused by an environmental effect event would result in greater ecological impacts (OECD: Ecological impact) than if the same effects would occur on other components within the ecological unit (OECD: Ecological footprint).

As an example, ecologically and biologically significant area criteria have been developed in Canada.

Key references

DFO. 2004. Identification of Ecologically and Biologically Significant Areas. DFO Canadian Science Advisory Secretariat, Ecosystem Status Report, 2004/006.

DFO. 2006. Identification of Ecologically Significant Species and Community Properties. DFO Canadian Science Advisory Secretariat. Science Advisory Report. 2006/041.

Conceptually, there are four main criteria to evaluate ecological and biological significance.

- Uniqueness
- Aggregation
- Fitness consequences
- Resilience and naturalness

7.1.2 Ecosystem component susceptibilities

(ISO Guide 73: Risk criteria)

Ecosystem component susceptibilities are considered to be the degree to which an organism, habitat, or ecosystem is open to impairment or change in its normal life cycle, functional properties, or processes as a result of inherent or predisposed weaknesses to environmental effects. These are expressed in terms of ecological indicators (OECD: Environmental indicator) and thresholds (OECD: Ecological amplitude). Examples include the following.

- As part of their life cycle, anadromous and catadromous species need passage between freshwater rivers and the sea for reproduction. They are susceptible to hydromorphological alterations that result in fish passage obstructions caused by dams or causeways or temporary water quality barriers, such as seasonal or spatial dissolved oxygen sags.
- Estuaries have varying flushing rates and are susceptible to nutrient regime disruptions as a result of land-based run-off of fertilizers or sewage.

Further reading

DFO. 2012. Definitions of harmful alteration, disruption or destruction (HADD) of habitat provided by eelgrass (*Zostera marina*). DFO Canadian Science Advisory Secretariat, Science Advisory Report, 2011/058.

McLusky, D. S., and Elliott M. 2004. The Estuarine Ecosystem: Ecology, Threats and Management, 3rd edn. Oxford University Press, Oxford. 216 pp.

Quality assurance checklist

- What ecological criteria are used to identify significant ecosystem components and their susceptibilities?
- What significant ecosystem components and environmental effects susceptibilities are found in the ecological unit?

7.1.3 Significant environmental services

(ISO Guide 73: Risk criteria)

Significant environmental services (OECD: Environmental services) are related to the social, cultural, and economic benefits derived from the ecosystem, such as recreational area, aesthetics, and spiritual or fishery resources, including wastewater regulation and recycling services (OECD: Economic benefits from environmental functions). Although several environmental services may depend on the ecological unit for their well-being, significant environmental services are considered as the goods and services where a change caused by an environmental effect event would result in greater social, cultural, or economic repercussions than if the same effects occur elsewhere in the ecological unit.

Further reading

DFO. 2009. Socio Economic Cultural Overview Assessment Values project (SECOA). The Southern Gulf of St Lawrence Coalition on Sustainability. 64 pp.

Lange, M., Burkhard, B., Garthe, S., Gee, K., Lenhart, H., Kannen, A., and Windhorst, W. 2010. Analysing Coastal and Marine Changes – Offshore Wind Farming as a Case Study: Zukunft Kueste – Coastal Futures Synthesis Report. LOICZ R and S Report No. 36. Available online at http://www.loicz.org/imperia/md/content/loicz/print/rsreports/loiczrs36_final-300810_online.pdf.

US EPA. 2010. Guidelines for preparing economic analysis. EPA 240-R-10-001. 297 pp. Available online at http://yosemite.epa.gov/ee/epa/eed.nsf/pages/Guidelines.html/$file/Guidelines.pdf.

7.1.4 Environmental services susceptibilities

(ISO Guide 73: Risk criteria)

Environmental service susceptibilities are considered to be the degree to which a social, cultural, or economic activity well-being is open to impairment of its normal operation or status owing to inherent or predisposed weaknesses to the loss of a goods or service caused by environmental effects events. These can be expressed as direct or indirect impacts or consequences. As an example, an anoxic event may directly affect the aesthetics of a coastal area, whereas economic devaluation of cottages and private properties could be considered as indirect impacts. These are expressed in terms of environmental indicators (OECD: Environmental indicator) and thresholds (OECD: Economically significant prices)

Further reading

Atkins, J. P., Burdon, D., Elliott, M., and Gregory, A. J. 2011. Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin, 62(2): 215–226.

Diedrich, A., Tintoré, J., Navinés, F., Tur, V., and Tortosa, E. 2008. System of Indicators for Integrated Coastal-zone Management in the Balearic Islands. Dictamen 5/2007 of the Economic and Social Council of the Balearic Islands (CES). Palma de Mallorca: CESS.

Rockloff, S., Helbers, D., Lockie, S., Moss, A., Sheltinga, D., and Cox, M. 2006. Integrated indicator framework for monitoring and reporting on biophysical health and social well-being in the coastal zone. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management Technical Report 82. 138 pp.

Quality assurance checklist

- In what area are the environmental criteria used to identify significant environmental services and their environmental effects susceptibilities?
- What environmental services depend on the ecosystem management outcomes and occur in the ecological unit?

7.1.5 Significant pressure loads

(ISO Guide 73: Risk source)

Significant pressure loads are related to the intensity of the drivers occurring in the zone of influence. Although there can be several drivers in the zone of influence that are creating pressures in the ecological unit, significant pressure loads are thought to contribute significantly to the risks of environmental effects occurring (OECD: Environmental debt).

Further reading

OSPAR. 2007. EcoQO Handbook. Handbook for the Application of Ecological Quality Objectives in the North Sea, 2nd edn. OSPAR Biodiversity Series, 307/2009. 66 pp.

Quality assurance checklist

- What risk criteria are used to characterize the intensity of the drivers and the loads of their pressures occurring in the zone of influence?
- What are the significant pressure loads in the zone of influence?

7.1.6 Environmental cause-and-effect pathways

(ISO Guide 73: Event)

(ISO 31010:2009 B.17 Cause-and-effect analysis)

Environmental cause-and-effect pathways (Figure 7.1) are a DPSIR graphic representation of the cause–effect relationships between driver activities and the mechanisms by which pressures ultimately lead to environmental effects. The link between the cause-and-effect relationships is considered to be a pathway connecting the driver to its pressure, the pressures to potential environmental effects, and subsequent impacts to susceptible ecosystem components and environmental services. The conceptual model is then used to conduct geospatial and temporal analysis of the ecosystem vulnerabilities of the ecological unit. In addition, these graphical models also guide the development of management strategies to identify where in the pathway management measures could effectively be applied to eliminate, control, or mitigate the risks of environmental effects.

Further reading

DFO. 2006. Pathways of Effects, in Habitat Protection and Sustainable Development Policy Manual. Available online at http://oceans.ncr.dfo-mpo.gc.ca/habitat/hpsd/risk/poe_e.asp.

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US DE. 1996. Guide for Developing Conceptual Models for Ecological Risk Assessments. ES/ER/TM-186. 21 pp. Available online at http://rais.ornl.gov/documents/tm186.pdf.

US EPA. 1997. Guidance on Cumulative Risk Assessment. Part 1: Planning and Scoping. 11 pp. Available online at http://www.epa.gov/spc/pdfs/cumrisk2.pdf.

Quality assurance checklist

- What cause-and-effect pathways link the drivers to their pressures and their respective environmental effect?

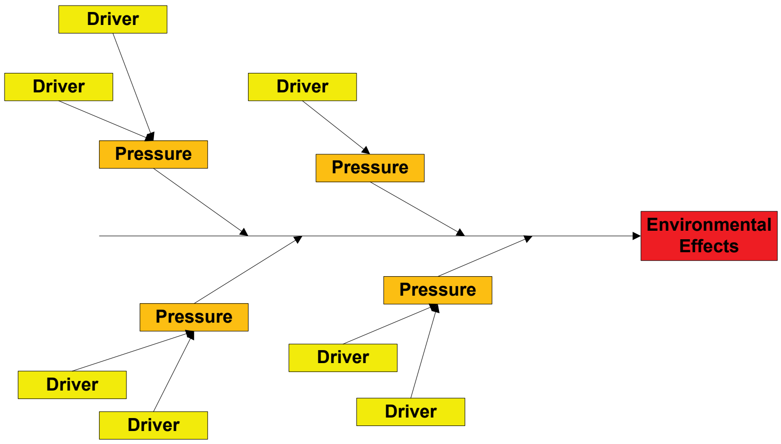

Figure 7.1. Environmental cause-and-effect pathways.

7.1.7 Environmental effects risk formulation

(ISO Guide 73: Risk perception)

Based on the environmental cause-and-effect pathways analysis, the risk formulation sets the profile of the ecosystem vulnerabilities of the ecological unit and environmental effects of concern. The result of this process is the environmental vulnerability profile for the ecological unit. The process is conducted in consultation with the governance structure of the management area and the stakeholders.

Key references

US EPA. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F. Available online at http://www.epa.gov/superfund/programs/nrd/era.htm.

US EPA. 2007. Application of watershed ecological risk assessment methods to watershed management. National Center for Environmental Assessment, Washington, DC; EPA/600/R-06/037F. Available online at http://www.epa.gov/ncea.

Problem formulation results in three products:

- assessment endpoints that adequately reflect management goals and the ecosystem they represent;
- conceptual models that describe key relationships between a stressor and assessment endpoint or between several stressors and assessment endpoints; and

- an analysis plan.

Three principal criteria are used to select ecological values that may be appropriate to assessment endpoints. In the context of this framework, they are ecological significance, susceptibility to known or potential pressures, and relevance to ecosystem management outcomes. The analysis plan should describe the objectives of the risk analysis to provide a better understanding of the extent to which ecosystem components and environmental services are exposed to environmental effect events resulting from drivers and pressures activities.

Further reading

Levin, P. S., Fogarty, M. J., Matlock, G. C., and Ernst, M. 2008. Integrated ecosystem assessments. US Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-92. 20 pp.

Moss, A., Cox, M., Scheltinga, D., and Rissik, D. 2006. Integrated estuary assessment framework. CRC for Coastal Zone, Estuary and Waterway Management. Technical Report, 69. 93 pp. Available online at www.coastal.crc.org.au.

Quality assurance checklist

- What risk criteria are used to identify the risk analysis endpoints in relation to the cause-and-effect pathways?
- What Delphic or empirical methods are used to complete the environmental vulnerability profile (ISO 31010: Risk management – Risk assessment techniques)?

7.1.8 Environmental vulnerability profile

(ISO Guide 73: Risk description)

An environmental vulnerability (ISO Guide 73: Vulnerability) profile of the ecological unit is a description of the environmental vulnerabilities in light of driver/pressure cause-and-effect pathways to environmental effects against the risk criteria. Within the context of an ecosystem component susceptibility to a specific environmental effect, it is a geospatial and temporal representation of the component in relation to the intensity of the drivers and load of their respective pressures. Not predicting where or when effects and impacts would occur, it establishes the spatial and temporal degree to which ecosystem components and environmental services are vulnerable to an environmental effect event, given the co-occurrence of the driver and pressures in the zone of influence (OECD: Ecosystem, environmental media, environmental services, environmental effects). The environmental vulnerability profile sets the risk analysis priorities.

The US Environmental Protection Agency has developed vulnerability assessment methods and tools.

Key references

US EPA. 2003. Regional Vulnerability Assessment for the Mid-Atlantic Region: Evaluation of Integration Methods and Assessments Results. EPA/600/R-03/082. 77 pp.

US EPA. 2008. Guidelines for Assessing Regional Vulnerabilities. EPA/600/R-08/078.

The application of regional vulnerability assessments methodology is generally to answer the following assessment questions:

- What is the overall condition of the region?

- What is the relative environmental condition, given all variables or a subset (e.g. those related to water quality)?
- Currently, what and where are the most pressing environmental risks for a region?
- What and where is the greatest risk in future?
- Where are the strategic planning or restoration priorities for a region?

The essence is the identification and quantification of ecosystem vulnerabilities to environmental hazards. Elliott *et al.* (2010) present a typology for hazards affecting the coastal and marine environment.

- Surface hydrological hazards
- Surface physiographic removal – chronic/long term
- Surface physiographic removal – acute/short term
- Climatological hazards – acute/short term
- Climatological hazards – chronic/long term
- Tectonic hazards – acute/short term
- Tectonic hazards – chronic/long term
- Anthropogenic microbial biohazards
- Anthropogenic macrobial biohazards
- Anthropogenic (introduced technological) hazards
- Anthropogenic (extractive technological) hazards
- Anthropogenic (chemical) hazards

Key reference

Elliott, M., Trono, A., and Cutts, N. D. 2010. Chapter 17: Coastal Hazards and Risk. *In* Coastal Zone Management, pp. 396–432. Ed. by D. R. Green. Thomas Telford Publishing, London.

Further reading

Marin, V., Moreno, M., Vassallo, P., Vezzulli, L., and Fabiano, M. 2008. Development of a multistep indicator-based approach (MIBA) for the assessment of environmental quality of harbours. ICES Journal of Marine Science, 65: 1436–1441.

US EPA. 1999. Mid-Atlantic Stressor Profile Atlas. EPA/600/C-99/003. 248 pp.

US EPA. 2003. Thresholds for Regional Vulnerability Atlas. Contract No. 68-C-98-187. 59 pp.

Quality assurance checklist

- In the ecological unit, what ecosystem components and environmental services are most vulnerable to environmental effects based on the drivers and associated pressures found in the zone of influence?

7.2 Risk analysis

(ISO Guide 73: Risk analysis)

Risk analysis is the step that establishes the consequences of an environmental effect event based on the environmental vulnerabilities profile completed in the risk identification. The analysis identifies the likelihood and magnitude of the significant environmental effects after analysis of existing management strategies. Once completed, ecosystem and environmental consequences are identified, as are policy repercussions of the consequences. The output of the analysis is an environmental risk profile that sets the priorities for the risk evaluation that will determine the level of acceptable risk and the need to take management action.

Quality assurance checklist

- What is the analysis plan for assessing the environmental effects, ecosystem impacts, environmental services impacts, and legislative and policy repercussions?
- What species, populations, or habitats are at risk, and how does this relate to the behaviour of the activity or the behaviour of any pollutants in the system?

7.2.1 Significant management strategies

(ISO Guide 73: Control)

Significant management strategies make up the entire suite of legislation, policy, programmes, management practices, and education strategies that have been implemented to prevent environmental effects in the management area (OECD: Environmental protection). Although several legislation and policy instruments are operating to ensure the overall health of the ecological unit, significant management strategies are considered to be the strategies, control, and mitigation measures that aim directly at eliminating, controlling, or mitigating the risks of environmental effects.

Quality assurance checklist

- What legislations, regulations, directives, policies, best management practices, standard operating procedures, and educational tools are applicable to identified drivers and pressures in the management area that control or mitigate the identified environmental effects?

7.2.2 Control and mitigation measure gap analysis

(ISO 31010:2009: Controls assessment)

(ISO 31010:2009: B.21 Bow-tie analysis)

Based on the environmental vulnerability profile and decisions about the environmental effect of concern and implicated drivers/pressures, the significant management strategies are used to conduct a gap analysis to identify areas where management measures may not be present, enforced, or effective in managing the pressures in reducing the risks of environmental effects. Such an analysis requires an extensive review of legislation, policy, management practices, standard operating procedures, and environmental quality guidelines and thresholds. The management measures identified during the risk identification are key inputs in the gap analysis.

MINOE was developed as an open-source tool by Dr Julia Ekstrom and researchers at Stanford University, sponsored by the Packard Foundation.

Key reference

Ekstrom, J. A., Lau, G., Cheng, J. C. P., Spiteri, D. J., and Law, K. H. 2010. MINOE: A software tool to analyse ocean management efforts in the context of ecosystems. Coastal Management, 38(5): 457–473.

The MINOE approach focuses on the textual links between ecological or socio-ecological systems of interest and the environmental effect of concern. The process involves the detailed review of existing statutes, regulations, policies, and best management practices (and others) that are relevant to the significant environmental effects to be avoided as per the ecosystem management outcomes via the identification of:

- keywords associated to the cause-and-effect pathway conceptual models;
- existing measures, jurisdictions, and authorities.

Subsequently, the findings are validated in consultation with the regulatory authorities via the identification of:

- the appropriate scale for examining the environmental effect;
- existing management measures;
- inconsistencies, ineffectiveness, or the absence of measures.

Further reading

Ekstrom, J. A., Lau, G., Cheng, J. C. P., Spiteri, D. J., and Law, K. H. 2010. Gauging agency involvement in environmental management using text analysis of laws and regulations. I/S: A Journal of Law and Policy for the Information Society, 6(2).

Ekstrom, J. A., Lau, G., Hardy, M., and Law, K. 2011. Application of the MINOE regulatory framework: Case studies: Proceedings of the 9th Annual International Conference on Digital Government Research. ACM, New York, USA.

Ekstrom, J. A., and. Young, O. R. 2009. Evaluating functional fit between a set of institutions and an ecosystem. Ecology and Society, 14(2): 16. Available online at http://www.ecologyandsociety.org/vol14/iss2/art16/.

Folke, C., Pritchard, L., Berkes, F., Colding, J., and Svedin, U. 1986. The problem of fit between ecosystem and institutions. IHDP Working Paper No. 2. International Human Dimensions Program on Global Environmental Change, Bonn, Germany. Available online at http://www.ihdp.uni-bonn.de/html/publications/workingpaper/wp02m.htm.

Holt, A. R., Godbold, J. A., White, P. C. L., Slater, A., Pereira, E. G., and Sloan, M. 2011. Mismatches between legislative frameworks and benefits restrict the implementation of the ecosystem approach in coastal environments. Marine Ecology Progress Series, 434: 213–228.

Wilson, J. A. 2006. Matching social and ecological systems in complex ocean fisheries. Ecology and Society, 11(1): 9. Available online at http://www.ecologyandsociety.org/vol12/iss1/art30/.

Young, O. R. 2002. The institutional dimensions of environmental change: fit, interplay and scale. Cambridge University Press, Cambridge, UK.

In addition, there is the need to determine the efficacy and possibility of compensation measures in cases where mitigation is not possible, for example, the loss of wetlands as a result of land claim. Compensation of habitats, components, or users can then be employed through, respectively, the creation or restoration of degraded or occupied habitats (such as depolderization), restocking of fish to account for a loss of stocks, or the financial compensation of users whose livelihoods have been affected by the developments. Each of these requires governance permissions and has economic consequences.

Further reading

Elliott, M., Burdon, D., Hemingway, K. L., and Apitz, S. 2007. Estuarine, coastal and marine ecosystem restoration: confusing management and science – a revision of concepts. Estuarine, Coastal and Shelf Science, 74: 349–366.

The graphical representation of the gap analysis (Figure 7.2) expands the initial DPSIR environmental cause-and-effect pathway. It is a simple graphic approach to indicate where control and mitigation measures are situated along the cause-and-effect pathways from the driver to the impacts. Using the DPSIR framework, it indicates where, along the pathways, responses are implemented to eliminate control or mitigate the risks of environmental effects. It also serves as a key communication and consultation tool.

Prevention and control measures are located on the left side of the "bow tie" (ISO 31010:2009 Bow-tie analysis); mitigation and restoration measures are located on the right side of the bow tie. Typically, enabling legislation is usually found between the drivers and their pressures. Prevention controls, such as best management practices, standard operating procedures, regulations, and management targets are found between the pressures and the environmental effect. These could be considered as critical control points that reduce the risks of environmental effect events. Marine environmental quality guidelines, marine protected areas, habitat protection legislation, and integrated management legislation are usually found between the environmental effect and the ecosystem components as well as environmental services.

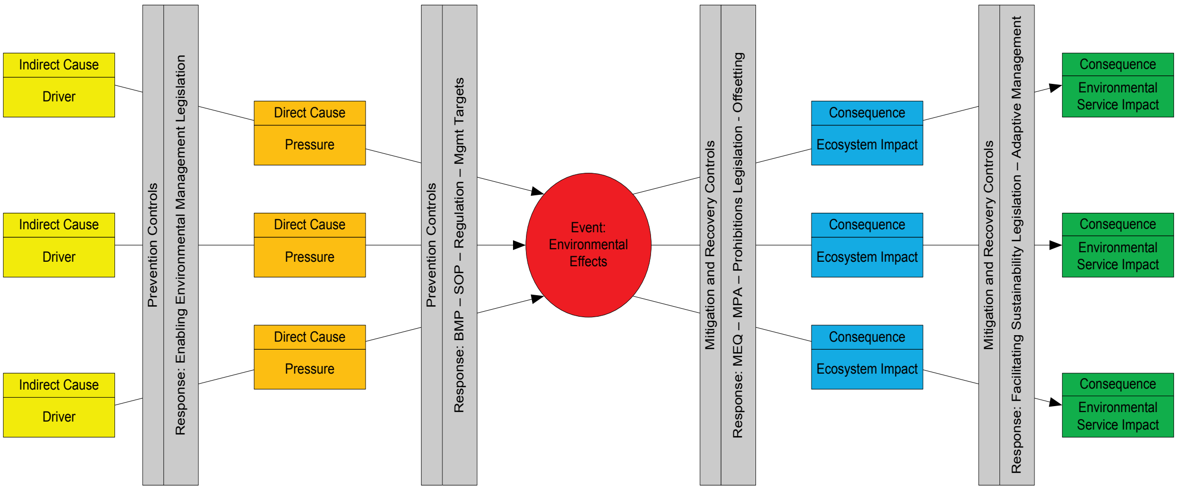

Figure 7.2. Control and mitigation measure gap analysis.

Quality assurance checklist

- Where along the cause-and-effect pathways are the existing legislations, regulations, directives, policies, best management practices, and standard operating procedures implemented in the management area?

7.2.3 Significant environmental effects

(ISO Guide 73: Residual risk)

Based on the control and mitigation management measure gap analysis, significant environmental effects are identified as the residual risks of environmental effects of existing management measures or the lack thereof. They can be considered as the net effect of the cumulative pressures attributable to the lack of or the effectiveness of existing management measures. The significant environmental effects are then retained for the subsequent assessment of likelihood, magnitude, and impacts that forms the basis for environmental risk profile.

Significant environmental effects are those that have the highest likelihood of occurring, based on the environmental vulnerability profile. These effects are tightly linked to the significant ecosystem components and environmental services in the ecological unit.

A Canadian class environmental assessment defines significant environmental effects.

Key reference

Transport Canada. 2007. Replacement Class Screening Report for Water Column Oyster Aquaculture in New Brunswick. Report of the Canadian Environmental Assessment Agency. Moncton, NB. 124 pp.

Significant environmental effects. A residual environmental effect is considered significant when it induces frequent, major levels of disturbance and/or damage and when the effects last longer than a year and extend beyond the boundary of the activity, despite management or mitigation measures. It is either reversible with active management over an extended term or otherwise irreversible.

Non-significant environmental effects. A residual environmental effect is considered not significant when it has infrequent, minor, or negligible levels of disturbance and/or damage, and when the effects last less than a year and are contained within the boundary of the activity following the application of management or mitigation measures. An effect that is not significant is reversible with or without short-term active management.

Further reading

CEARC and US NRC. 1986. Cumulative Environmental Effects: A Binational Perspective. Minister of Supply and Services Canada 1985, Catalogue No. En 106-211985. 175 pp.

Quality assurance checklist

- What criteria are used to determine the level of residual risk to identify the significant environmental effect of the ecological unit?

7.2.4 Environmental effect probability and magnitude

(ISO Guide 73: Likelihood)

(ISO Guide 73: Exposure)

Based on the significant environmental effect, the likelihood or probability of an environmental effect event is ascertained. Predictive models can provide insight into the likelihood of effects by combining driver intensity, pressure loads, and ecosystem component susceptibilities. However, additional attributes are needed to describe and classify the magnitude of the environmental effect, as defined by the risk criteria. Not meant as an exhaustive list, attribute considerations include the magnitude of the environmental effect in terms of its geographical extent, duration, and frequency.

- Is the effect localized in one of the management areas or is it associated with an individual or point-source pressure?

- Does the effect occur in multiple management areas, or is it associated with a driver of a given sector and its pressures?
- Does the effect occur across the ecological unit, or is it associated with multiple drivers and their pressures?

Quality assurance checklist

- What Delphic or empirical methods are used to assess the likelihood or probability and magnitude of the environmental effect event (ISO 31010: Risk management – Risk assessment techniques)?

7.2.5 Ecosystem component impacts

(ISO Guide 73: Consequence)

Based on the significant environmental effect, the impacts to ecosystem components and processes, such as species, habitat, community properties, and productivity, are ascertained (OECD: Ecosystem, ecosystem impact, ecosystem amplitude). Predictive models can provide insight into the potential impacts, based on existing ecological knowledge and risk criteria. However, additional attributes are needed to describe and classify the severity of the impacts, based on the risk criteria. Not meant as an exhaustive list, examples of attribute considerations include the severity of the impacts in terms of population, habitat, and ecosystem, as well as duration and reversibility.

- Is the impact localized to a number of organisms or local habitat where recovery is within one generation or season?
- Does the impact affect a portion of a population, habitat, or ecosystem process where recovery is within multiple generations or seasons?
- Does the impact affect several populations, habitats, or ecosystem processes where recovery is unpredictable or not possible?

Further reading

DFO. 2012. Definitions of harmful alteration, disruption or destruction (HADD) of habitat provided by eelgrass (*Zostera marina*). DFO Canadian Science Advisory Secretariat, Science Advisory Report, 2011/058.

Lange, M., Burkhard, B., Garthe, S., Gee, K., Lenhart, H., Kannen, A., and Windhorst, W. 2010. Analysing Coastal and Marine Changes – Offshore Wind Farming as a Case Study: Zukunft Küste – Coastal Futures Synthesis Report. LOICZ R and S Report, 36. Available online at http://www.loicz.org/imperia/md/content/loicz/print/rsreports/loiczrs36_final-300810_online.pdf.

Quality assurance checklist

- What Delphic or empirical methods are used to assess and classify the severity of ecosystem impacts (ISO 31010: Risk management – Risk assessment techniques)?

7.2.6 Environmental services impacts

(ISO Guide 73: Consequence)

Based on the significant environmental effects, the impacts to environmental services (OECD: Environmental services), and potential consequences in terms of social, cultural, and economic repercussions are ascertained (OECD: Environment). Predictive models can provide insight into the potential impacts, based on existing social, cultural, and economic knowledge. However, additional attributes are needed to describe and classify the severity of the impacts, based on the risk criteria. Not meant as an exhaustive list, examples of attribute considerations include social, cultural, and economic consequences.

- Is the impact localized to a number of individuals in terms of their routine activities or additional costs of operation?
- Does the impact affect a local community in terms of their traditional activities or livelihood and employment?
- Does the impact affect an entire sector or region where traditional activities or livelihood and employment are lost?

Quality assurance checklist

- What Delphic or empirical methods are used to assess and classify the severity of environmental services impacts in terms of social, cultural, and economic goods and services repercussions (ISO 31010: Risk management – Risk assessment techniques)?

7.2.7 Legislative policy repercussions

(ISO Guide 73: Consequence)

Based on the significant environmental effects, the legislative and policy repercussions are ascertained (OECD: Environmental protection, environmental activities). For example, these include legislative and policy repercussions in terms of legislative obligations and liabilities, including policies and programme capacities. However, attributes are needed to describe and classify the repercussions within the context of the management area. The governance mechanisms may be at various hierarchical levels, being regional or national within a larger bloc, such as the regional seas conventions (e.g. HELCOM, OSPAR) or the European Union, or internationally, such as IMO or UNCLOS. Not meant as an exhaustive list, examples of attribute considerations include the following.

- Are the repercussions manageable within existing regional programmes, organizational structures, and human/financial resources?
- Will the repercussions result in litigation and require national organizational changes and additional human/financial resources?
- Will the repercussions result in the need for legislative change and new policies, programmes, and governance structures?

Further reading

TBS. 2004. Integrated Risk Management. Implementation Guide. Treasury Board Secretariat of Canada. Catalogue No. BT22-92/2004.

Quality assurance checklist

- What criteria are used to assess and classify the legislative and policy repercussions?

7.2.8 Environmental risk profile

(ISO Guide 73: Level of risk)

The environmental vulnerability profile described vulnerabilities in terms of potential environmental effects and implicated drivers/pressures, ecosystem components, and environmental services (OECD: Ecosystem, environmental media, environmental services). In risk identification, the vulnerability profile provided the basis for triage and priority setting for the risk analysis. In contrast, the environmental risk profile is more predictive in nature and identifies spatial and temporal areas of highest risk, based on the likelihood and magnitude of environmental effects, the impacts to the ecosystem and environmental services, as well as the legislative policy repercussions. It represents the current effectiveness of existing management measures and the lack thereof. It also proposes enhancements or new control and mitigation measures (OECD: Environmental protection) to further reduce the risks of environmental effects. It is the basis for informing management decisions about the level of acceptable risks and the need to enhance or take additional management measures.

The EU directive on the strategic environmental assessments of environmental effects provides the basis to establish the risk profile.

Key reference

EC. 2001. Directive 2001/42 of the EU parliament and of the Council on the assessment of the effects of certain plans and programmes on the environment.

Characteristics of the effects and of the area likely to be affected, particularly the:

- intensity of the pressures, duration, and spatial extent of the footprint;
- probability, duration, frequency, and reversibility of the effects;
- cumulative and in-combination nature of the effects;
- transboundary nature of the effects;
- risks to human health or the environment (e.g. attributable to accidents);
- magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);

including the value and vulnerability of the area likely to be affected because of:

- the behaviour of the activity or the pollutants in the environment;
- special natural characteristics or cultural heritage;
- exceeded environmental quality standards or limit values;
- intensive land use;
- the effects on areas or landscapes which have a recognized national, community, or international protection status.

Based on the ecosystem management outcomes and the environmental effects risk criteria (ISO Guide 73: Risk criteria), the profile is a comprehensive risk ranking of environmental effects (OECD: Environmental effect) and their existing management strategies (OECD: Environmental protection). Considered as a valuable communication medium, geospatial representation of the risk ranking is used to indicate areas of low, medium, and high risks. The following references provide insight into environmental risk profile approaches.

Further reading

Australia Department of Environment and Resource Management. 2011. A framework for assessing the health of, and risk to, Queensland's lacustrine (lake) and palustrine (swamp) wetlands. Component A: the framework. Version 2.3, Queensland Wetlands Program, Brisbane, QLD.

Greig, L. 2012. Geospatial Risk Characterization Workshop II: Tools for Ecosystem-based Approaches to Support Integrated Decision Making – Workshop Synthesis. Canadian Manuscript Report, Fisheries and Aquatic Sciences. 92 pp.

Heslenfeld, P., and Enserink, E. L. 2008. OSPAR ecological quality objectives: the utility of health indicators for the North Sea. ICES Journal of Marine Science, 65: 1392–1397.

Johnson, D. 2008. Environmental indicators: their utility in meeting the OSPAR Convention's regulatory needs. ICES Journal of Marine Science, 65: 1387–1391.

Stelzenmüller, V., Lee, J., Garnacho, E., and Rogers, S. 2010. Assessment of a Bayesian Belief Network – GIS framework as a practical tool to support marine planning. Marine Pollution Bulletin, 60: 1743–1754.

Quality assurance checklist

- In the ecological unit, what are the ecosystem components and environmental services that are most at risk to environmental effects as they relate to the drivers and associated pressures found in the zone of influence?

7.3 Risk evaluation

(ISO Guide 73: Risk evaluation)

Informed by the ecological and environmental consequences as well as the policy repercussions identified in the risk analysis, the risk evaluation ascertains the need to take management action based on the level of risk considered acceptable by the competent authority in consultation with regulators, stakeholders, and the public. The decision is also informed by the previous state of the environmental effects reports and performance and effectiveness audits.

7.3.1 Control and mitigation measure assessment

(ISO Guide 73: Risk attitude)

In addition to the environmental risk profile, past reports on the status and trends of the state of environmental effects in the ecological unit and the management performance audits findings (ISO 14050:2009(E/F/R): Audit finding) in the management area form the basis of this assessment. The step also involves extensive consultations with regulators, stakeholders, and the public to determine the level of risk that is acceptable to everyone. Based on the acceptable level of risk (ISO Guide 73: Risk retention), the competent authority has to determine the need of either not implementing any management measures and accepting the risks or implementing enhanced or new management measures to eliminate, control, or mitigate the risks to an acceptable level in consideration of the environmental effect risk criteria (Figure 7.3). In this framework:

- Accepting the risks implies that the environmental risk profile is acceptable and that the management measures are considered adequate, given their level of effectiveness and cost of implementation.
- Eliminating the risks implies that the environmental risk profile is of such a concern that management measures that regulate all drivers in the management area are required. These could include marine conservation and protection areas or marine spatial and temporal management of all activities.

- Controlling the risks implies that the environmental risk profile is of concern and that management measures applied to the implicated drivers and pressures are required. These could include best management practices or standard operating procedures, regulations, or management targets.
- Mitigating the risks implies that the environmental risk profile is of concern and that measures that regulate specific pressures are required. These could include marine environmental quality guidelines or restoration or adaptive measures.
- Compensating the components damaged by the activity in cases where mitigation is not possible.
- Tolerating the activity in cases where neither mitigation nor compensation is possible, but the activity has been deemed to be necessary in the national interest.

During this evaluation, existing control and mitigation measures are assessed to determine if enhancements are feasible, based on available technologies, scientific knowledge, and implantation constraints. New options are also identified as possible solutions.

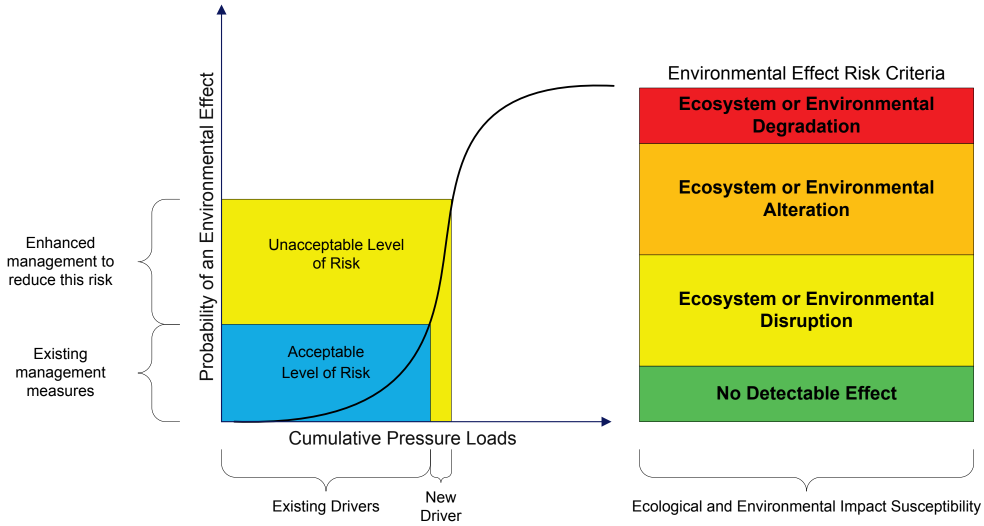

Figure 7.3. Control and mitigation assessment considerations.

Further reading

WB and CIDA. 2009. Persistent Organic Pollutants Tool Kit. Management Options Evaluations Tool. Regional Capacity Building Program for Health Risk Management of Persistent Organic Pollutants (POPs) in South East Asia. Available online at http://www.popstoolkit.com/riskmanagement/module/step3.aspx.

Quality assurance checklist

- In the ecological unit, what are the ecosystem components and environmental services that are most at risk to environmental effects because of the drivers and associated pressures found in the zone of influence?

7.3.2 Control measures not required

(ISO Guide 73: Risk acceptance)

If the risks are acceptable to regulators, stakeholders, and the public, additional management measures are not required. However, environmental effects monitoring (ISO Guide 73: Monitoring; OECD: Monitoring) is still required to follow and report on the status of and trends in the state of the environmental effects over time. As mentioned earlier, these reports are an important piece of information for future risk evaluations. They also provide feedback to regulators, stakeholders, and the public as to their assumptions in terms of their acceptability of risk and the decisions that control measures are not required. This decision terminates the risk assessment, and the process will not proceed to the risk treatment step.

7.3.3 Control measures adequate

(ISO Guide 73: Risk tolerance)

If the risks are tolerable to regulators, stakeholders, and the public, existing control and mitigation measures are considered adequate. However, environmental effects monitoring (ISO Guide 73: Monitoring; OECD: Monitoring) is required to follow and report on the status and trends in the state of the environmental effects over time as an indicator of the effectiveness of the existing control and mitigation measures. They also provide feedback to regulators, stakeholders, and the public as to their assumptions in terms of their acceptability of risk and the decisions that existing control measures are adequate. As mentioned earlier, these reports are also an important piece of information for future risk evaluations. In addition, performance audits (ISO Guide 73: Risk management audit) and corrective actions are required to ascertain that control measures have been implemented and operated as per the specifications outlined in the management plans. This decision terminates the risk assessment, and the process will not proceed to the risk treatment step.

7.3.4 Enhanced new control measures required

(ISO Guide 73: Risk aversion)

If the risks are unacceptable to regulators, stakeholders, and the public, enhancements to existing control and mitigation measures or new measures are required. Any new or enhanced control and mitigation measures identified in the environmental risk profile will form the basis for the development of new management strategies in the risk treatment. Potential enhancements and new control measures are also identified.

8 Risk treatment

(ISO Guide 73: Risk treatment)

Once a decision has been made to implement new or enhanced management strategies during the risk evaluation step, risk treatment evaluates options for feasibility and effectiveness. Once the management strategies are selected, the management plan is developed and implemented, and after the plan has been in operation for a given period and as part of the monitoring and review requirements, environmental effects monitoring is used to ascertain the effectiveness of the plan in reducing the risk of environmental effects, while performance audits are used to ensure that the management strategies have been implemented as planned.

8.1 Control and mitigation measure options

(ISO Guide 73: Control)

The risk evaluation identified options for the development of new or enhanced control and mitigation measures. These options form the basis for the following management scenario cost–benefit analysis.

Quality assurance checklist

- What is the reliability of the proposed control and mitigation measures in reducing the risk of environmental effects?

8.2 Management scenario costs and benefits

(ISO Guide 73: Risk retention)

Based on the risk evaluation, the competent authority needs to identify the most cost-effective management strategies in consultation with regulators and stakeholders. Based on the gap analysis of control and mitigation measures and subsequent assessments, control and mitigation options are considered in terms of their position along the cause-and-effect pathway. In risk management, prevention controls implemented nearest to the source of the risk (ISO Guide 73: Risk source) tend to be more cost-effective than mitigation measures aimed at reducing impacts after an environmental effect has occurred (Figure 8.1).

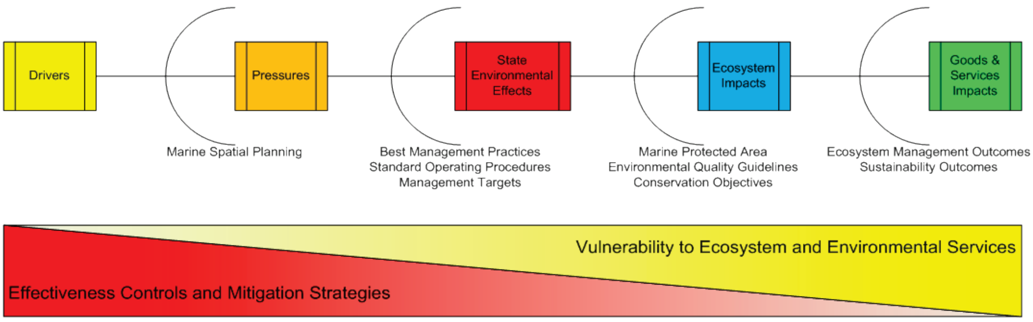

Figure 8.1. Control and mitigation measure effectiveness.

For each option, management scenario cost–benefit analysis is conducted to identify the most effective measures for reducing the risk of environmental effects events, while remaining feasible to implement under existing legislation, technological knowledge, economic-sector capacity, and stakeholder engagement. Cost considerations also include governance and economic-sector implementation, administration, and operations. The benefits include the effectiveness of the management measure to eliminate, control, or mitigate the risks of environmental effects. Management scenario analysis also plays an important role in simulating potential impacts of management options in relation to the ecosystem management outcomes.

Key references

Hopkins, T. S., Bailly, D., and Støttrup, J. G. 2011. A systems approach framework for coastal zones. Ecology and Society, 16(4): 25.

SPICOSA. 2010. Guide to System Design. Napier University, Edinburgh, 2010 – part of the SPICOSA SAF handbook. Available online at http://www.coastal-saf.eu/.

Further reading

EU. 2002. Guide to cost–benefit analysis of investment projects. DG Regional Policy European Commission. 135 pp.

Hanley, N., and Clive, L. 1993. Cost–benefit Analysis and the Environment. Edward Edgar Publishing Inc., Northampton, MA, USA. 275 pp.

Hopkins, T. S., Bailly, D., Støttrup, J. G., Sandberg, A., and Elmgren, R. 2012. A systems approach for sustainable development in coastal zones. Special Feature Volume, Ecology and Society. Available online at http://www.ecologyandsociety.org/issues/view.php?sf=67.

Moksness, E., Dahl, E., and Støttrup, J. 2009. Integrated Coastal Zone Management. Wiley–Blackwell, Oxford. 430 pp.

OECD. 2006. Cost–benefit Analysis and the Environment: Recent Developments. 314 pp.

TBS. 2007. Canadian Cost–Benefit Analysis Guide: Regulatory Proposals. Treasury Board of Canada Secretariat. Catalogue No. BT58-5/2007.

Tett, P., Sandberg, A., and Mette, A. 2011. Sustain Coastal Systems. Dunedin Academic Press, Scotland. 173 pp.

Quality assurance checklist

- What Delphic or empirical methods are used to assess the costs and benefits of the proposed measures (ISO 31010: Risk management – Risk assessment techniques)?
- Has the analysis considered the costs to stakeholder and bureaucratic process, quality assurance, and implementation?

8.3 Selected management strategies

(ISO Guide 73: Risk treatment)

In consultation with regulators and stakeholders, management strategies (OECD: Environmental protection) are selected based on the management scenario cost–benefit analysis. The "seven tenets for sustainable environmental management" also provide high-level considerations for selecting management options to develop the management plan (Elliott, 2011).

Key reference

Elliott, M. 2011. Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – a numbered guide. Marine Pollution Bulletin, 62: 651–655.

Elliott (2011) states that our actions must be:

- environmentally/ecologically sustainable, i.e. that the measures will ensure the safeguarding of ecosystem features and functioning, as well as fundamental and final ecosystem services, as good for nature now as in future;
- technologically feasible, i.e. that the methods, techniques, and equipment for ecosystem protection are available;
- economically viable, i.e. that a cost–benefit assessment of the environmental management indicates viability and sustainability at a reasonable and tolerable cost;
- socially desirable/tolerable, i.e. that the environmental management measures are as required or at least are understood and tolerated by society as being required; that societal benefits are delivered;
- legally permissible, i.e. that there are regional, national, or international agreements and/or statutes that will allow and/or force the management measures to be performed;
- administratively achievable, i.e. that the statutory bodies such as governmental departments, environmental protection, and conservation bodies are in place and functioning to allow successful and sustainable management;
- politically expedient, i.e. that the management approaches and philosophies are consistent with the prevailing political climate, have the support of political leaders, and are in line with mandated policy.

Further reading

TBS. 2007. Assessing, selecting, and implementing instruments for government action. Treasury Board of Canada Secretariat. Catalogue No. BT58-3-2007.

TBS. 2007. Guideline for effective regulatory consultation. Treasury Board of Canada Secretariat. Catalogue No. BT58-2/2007.

TBS. 2009. Regulatory Impact Assessment Statement Writer's Guide. Treasury Board of Canada Secretariat. Catalogue No. BT53-16/2009E-PDF.

Quality assurance checklist

- What criteria are used to determine that the seven tenets of sustainable environmental management were met?

8.4 Development of the management plan

(ISO Guide 73: Risk treatment)

The development phase of the management plan includes the step that requires the most intensive consultation (ISO Guide 73: Communication and consultation). To ensure transparency and credibility, even the table of contents should be agreed upon by all parties. In addition to the management strategies, the function of the management plan must also clearly identify the competent authority that is accountable for the implementation, as well as the regulators and stakeholders (ISO Guide 73: Risk sharing) that have agreed to implement the control and mitigation measures in the management area (ISO Guide 73: Risk management plan). The plan development should follow a timeline that is well established and agreed upon.

Further reading

CEAA. 2010. Regulations respecting the coordination by federal authorities of environmental assessment procedures and requirements. Government of Canada, SOR/97-181.

TBS. 2009. Handbook for regulatory proposals: performance measurement and evaluation plan. Treasury Board of Canada Secretariat. Available online at http://www.tbs-sct.gc.ca.

Quality assurance checklist

- What are the communication plans, consultation processes, and decision-making points for the development life cycle of the management plan?

8.5 Risk management plan

(ISO Guide 73: Risk management plan)

Legislative and governance accountabilities. For each ecosystem management outcome, the plan identifies the competent authority that is accountable (ISO Guide 73: Risk owner) for achieving the outcomes, and is responsible for the coordination and implementation of the plan. It also identifies the other jurisdictional authorities that have agreed to collaborate in the implementation of the control and mitigation measures outlining complementary policies, while respecting territorial and regulatory powers (ISO Guide 73: Risk sharing) as well as implicated industry sectors and stakeholders (ISO Guide 73: Stakeholder). The document sets the geographical boundaries of the ecological unit as the ecosystem basis for management, as well as the boundaries of the management areas.

Administrative business processes. It delineates the roles and responsibilities of the competent authority, the jurisdictional approval authorities, and the coordinating, administrative, technical, and stakeholder advisory bodies. It describes the business processes for the implementation and management of the plan, including meetings, secretariat functions, project plan management, and reporting timelines. It also describes and tracks human and financial resources for the administration of the plan. The plan implementation sets the timelines and resources involved in the implementation and subsequent operation of the plan. A project plan should include a project charter and deployment proposal with timelines, tasks, and implicated human and financial resources. It should identify who is accountable for the implementation, including progress-reporting requirements to the governance and stakeholders of the management area. Public communications and press releases are also included.

Driver/pressure control mitigation management strategies. Environmental effects management measures are described relative to each ecosystem management outcome. Measures are implemented to eliminate, control, or mitigate the risk of environmental effects (ISO Guide 73: Control). The measures may be expressed as spatial, temporal, or procedural requirements applying to all or specific drivers, such as best management practices or standard operating procedures. They also include mitigation measures in relation to specific pressures, such as environmental quality guidelines and standards (OECD: Environmental quality standard).

Performance measurement framework. From a quality assurance perspective (ISO 9001:2000 Quality management systems), performance measurement is a fundamental building block to verify that the management plan is achieving the ecosystem management outcomes (ISO Guide 73: Risk management audit). A performance measurement framework includes definitions of the metrics and indicators, data collection and validation procedures, data analysis protocols and methods, as well as reporting templates. Following adaptive management principles, such a framework sets the basis for all subsequent performance and effectiveness audits and non-conformity corrective actions to the management plan. A performance measurement framework is used to track and collect data including:

- governance and administrative progress of the deliverables for each step of the risk analysis project plan;
- decision-making, peer-review, and advisory processes in relation to the established terms of references and protocols;
- implementation and maintenance of the management measures.

Environmental effects monitoring plan. As with the performance measure framework, environmental effects monitoring (ISO Guide 73: Monitoring; OECD: Monitoring) is a fundamental step in verifying that the management plan is achieving the ecosystem management outcomes. It also includes definitions of the metrics and indicators, data collection, validation procedures, data analysis protocols, and methods as well as reporting templates. However, its primary function is to track the status and trends of the environmental effects occurring within the scale of the ecological unit. The monitoring plan has to discriminate between naturally occurring changes and those caused by the drivers of human activity that are linked to the managed pressures. Although challenging, the plan's protocols and methods have to detect changes occurring outside natural variations.

Reporting requirements. To ensure transparency, credibility, and engagement of all parties involved, reporting requirements address all aspects of the risk communication principles and requirements (ISO Guide 73: Communication and consultation). A suite of standard report formats, technical content, and release frequencies are described for each type of audience (ISO Guide 73: Risk reporting). It considers:

- scientific, technical, and policy documentation requirements for policy and decision-makers;
- information and technical educational aspects for industry sectors and communities of interests;
- information and educational aspects for the public.

The suite of documents must ensure continuity and links from general documentation to the detailed technical and policy documentation.

Further reading

DFO. 2007. The Eastern Scotian Shelf Integrated Ocean Management Plan. Fisheries and Oceans Canada, DFO/2007-1229. 70 pp.

UNEP/MAP/PAPRAC. 2008. Protocol on integrated coastal-zone management in the Mediterranean. Available online at http://www.unepmap.org.

UNESCO. 2006. A Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management. IOC Manuals and Guides, 46; ICAM Dossier, 2. UNESCO, Paris.

Quality assurance checklist

- Who is accountable for implementing and managing the operations of the risk management plan?
- What is the project plan approval process for the implementation and management?

- What are the human resources, financial planning, and reporting requirement for the implementation and management of the risk management plan?

8.6 Environmental effects monitoring

(ISO Guide 73: Monitoring)

(OECD: Monitoring)

Environmental effects monitoring is required to follow and report on the trends in the state of the environmental effects over time. These reports are important pieces of information for future risk evaluations. They also provide feedback to regulators, stakeholders, and the public as to their assumptions about their acceptability of risk and the agreed-upon management strategies. It should be noted that indicators (OECD: Environmental indicator) and methodologies must be able to detect the status and trends of environmental effects outside natural variation. The selected indicators must be linked to the environmental effects risk criteria and the ecosystem management outcomes. The data generated by this monitoring programme are used primarily to determine the effectiveness of the management measures.

8.6.1 State of the environmental effects

(ISO Guide 73: Risk reporting)

The state of the environmental effects (OECD: Environmental quality) report is used primarily to ascertain the effectiveness of the management measures in reducing the risks of environmental effects events. Not intended to be a comprehensive list, the type of questions that the report should consider include the following.

- Is the observed status and trends an indication of driver activity and not naturally occurring changes in the ecosystem?
- Are the reductions in the status and trends of the environmental effects an indication that the management measures are effective at reducing risks?
- Are the changes in status and trends of the environmental effects an indication that the management measures are not effective?
- Are the changes in status and trends of the environmental effects an indication that there are natural factors or drivers that were not considered in the initial risk assessment and management plan development?

The state of the environmental effects report is an essential element of the quality-assurance feedback loop of any management system. The report ascertains the effectiveness of implemented control and mitigation measures and may trigger a review of the initial environmental risk profile assumptions. Such reports are key communication tools (ISO Guide 73: Communication and consultation) in support of the governance processes in consultation with regulators, stakeholders, and the public within the management area. Stakeholders (ISO Guide 73: Stakeholder) that implement management measures have to be informed of their effectiveness in order to justify their investment of human and financial resources. For public reporting, report cards may be used to summarize the technical aspects of the report.

The monitoring methods and indicators for monitoring have to fulfil a set of criteria to be effective. Elliott (2011) provides a list of required properties of indicators and monitoring parameters for successful marine management (Table 8.1).

Key reference

Elliott, M. 2011. Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – a numbered guide. Marine Pollution Bulletin, 62: 651–655.

Table 8.1. The required properties of indicators and monitoring parameters for successful marine management.

Property	Explanation
Anticipatory	Sufficient to allow the defence of the precautionary principle, as an early warning of change, capable of indicating deviation from that expected before irreversible damage occurs.
Biologically important	Focuses on species, biotopes, communities, etc.; important in maintaining a fully functioning ecological community.
Broadly applicable and integrative over space and time	Usable at many sites and over different periods to give an holistic assessment that provides and summarizes information about many environmental and biotic aspects; to allow comparisons with previous data to estimate variability and to define trends and breaches with guidelines or standards.
Concrete and results focussed	We require indicators for directly observable and measurable properties rather than those that can only be estimated indirectly; concrete indicators are more readily interpretable by diverse stakeholders who contribute to management decision-making.
Continuity over time and space	Capable of being measured over appropriate ecological and human time- and space-scales to indicate recovery and restoration.
Cost effective	Indicators and measurements should be cost effective (financially non-prohibitive), given limited monitoring resources, i.e. with an ease/economy of monitoring. Monitoring should provide the greatest and quickest benefits to scientific understanding and interpretation, to society, and to sustainable development. This should produce an optimum and defensible sampling strategy and the most information possible.
Grounded in theory and relevant and appropriate	Indicators should reflect features of ecosystems and human impacts that are relevant to achieving operational objectives; they should be scientifically sound and defensible and based on well-defined and validated theory. They should be relevant and appropriate to management initiatives and understood by managers.
Interpretable	Indicators should reflect the concerns of, and be understood by, stakeholders. Their understanding should be easy and equate to their technical meanings, especially for non-scientists and other users; some should have a general applicability and be capable of distinguishing acceptable from unacceptable conditions in a scientifically and legally defensive way.
Low redundancy	The indicators and monitoring should provide unique information compared with other measures.
Measurable	Indicators should be easily measurable in practice using existing instruments, monitoring programmes, and analytical tools available in the relevant areas, to the required accuracy and precision, and on the time-scales needed to support management. They should have minimum or known bias (error), and the desired signal should be distinguishable from noise, or the noise (inherent variability in the data) should at least be quantified and explained, i.e. have a high signal-to-noise ratio. They need to be capable of being updated regularly, being operationally defined and measured, with accepted methods and analytical/quality control/quality assurance, and with defined detection limits.
Non-destructive	Methods used should cause minimal and acceptable damage to the ecosystem and should be legally permissible.
Realistic and attainable (achievable)	Indicators should be realistic in their structure and measurement and should provide information on a “need-to-know” basis rather than a “nice-to-know” basis. They should be attainable (achievable) within the management framework.
Responsive feedback to management	Indicators should be responsive to effective management action and regulation, and provide rapid and reliable feedback on the findings. Such feedback loops should be determined and defined prior to using the indicator.
Sensitive to a known stressor or stressors	The trends in the indicators should be sensitive to changes in the ecosystem properties or impacts, to a stressor or stressors that the indicator is intended to measure, and also sensitive to a manageable human activity; they should be based on an underlying conceptual model, without an all-or-nothing response to extreme or natural variability, therefore potentially useful in a diagnostic capacity.

Socially relevant	Understandable to stakeholders and the wider society or at least predictive of, or a surrogate for, a change important to society.
Specific	Indicators should respond to the properties they are intended to measure rather than to other factors, and/or it should be possible to disentangle the effects of other factors from the observed response (therefore having a high reliability/specificity of response and relevance to the endpoint).
Time-bounded	The date of attaining a threshold/standard should be indicated in advance. They are likely to be based on existing time-series data to help set objectives and also based on readily available data and those revealing temporal trends.
Timely	The indicators should be appropriate to management decisions relating to human activities, and therefore they should be linked to that activity, thus providing real-time information for feedback into management, giving remedial action to prevent further deterioration and to indicate the results of or need for any change in strategy.

Further reading

Borja, Á, Elliott, M., Carstensen, J., Heiskanen, A-S., and van de Bund, W. 2010. Marine management – towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Marine Pollution Bulletin, 60: 2175–2186.

CESD. 2011. Chapter 5: A Study of Environmental Monitoring. Report of the Commissioner of the Environment and Sustainable Development 2009. Catalogue No. FA1-2/2011-2-0E-PDF. Available online at http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201112_e_36027.html.

Clayton, P. D., Fielder, D. P., Howell, S., and Hill, C. J. 2006. Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM): a conservation values assessment tool for wetlands with trial application in the Burnett River catchment. Published by the Environmental Protection Agency, Brisbane. Available online at http://www.epa.qld.gov.au/wetlandinfo/resources/static/pdf/AQUABAMM/register/p02017ab.pdf.

EU EEA. 2000. Questions to be answered by a State-of-the-environment Report: The first list. Technical Report, 47. 116 pp.

Scheltinga, D. M., Counihan, R., Moss, A., Cox, M., and Bennett, J. 2004. Users' guide for estuarine, coastal and marine indicators for regional NRM monitoring. Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management. 198 pp. Available online at www.coastal.crc.org.au.

Quality assurance checklist

- What criteria can confirm that the management strategies and measures are achieving the desirable results?
- What frequencies, methods, indicators, and thresholds are required to monitor the status and trends of the environmental effects?
- Who is responsible for conducting the data collection and analysis?
- Who is responsible for preparing the effects report and responding to the results?

8.7 Performance effectiveness audits

(ISO Guide 73: Risk management audit)

Following the principles of adaptive management, performance and effectiveness audits and assessments are used to ascertain if the plan is meeting ecosystem management outcomes. An audit is a planned, independent, and documented evaluation to determine whether or not an agreed-upon management plan and measures are being implemented. It determines the effectiveness of the implementation as well as the performance of the institutions and processes in the administration of the plan. When nonconformities (ISO 14050:2009 Nonconformity) are found, corrective actions (ISO 14050:2009: Corrective action) are implemented to the plan or to the administrative processes as required. The International Organization for Standardization provides a broad range of tools to conduct such audits.

Key references

ISO. 2000. Quality management systems – Requirements. International Standards Organization, ISO 9001:2000.

ISO. 2002. Guidelines for quality and/or environmental management systems auditing. International Standards Organization, ISO 19011:2002(E).

ISO. 2004. Environmental management systems – Requirements with guidance for use. International Standards Organization, ISO 14001:2004.

ISO. 2009. Environmental management – Vocabulary. International Standards Organization, ISO 14050:2009(E/F/R).

A key element of an audit is its ability to be verifiably evidence-based, following a systematic process to ensure reliability and reproducible results. An audit includes the gathering of information and evidence regarding conformity (ISO/IEC 17021:2006(E): Conformity assessment) to management plans and measures. It focuses particularly on the links between the management measure implementation and administrative processes. Audits seldom focus on the effectiveness of management measures relative to ecosystem management outcomes. An audit can provide insight regarding effectiveness issues of the technologies or methods used and their performance. However, environmental effects monitoring is better positioned to determine if the management strategies and measures are effective at reducing the risks of environmental effects.

8.7.1 Control measure corrective action

(ISO Guide 73: Risk reporting)

In this framework, a nonconformity (ISO 14050:2009: Nonconformity) is a deviation from a management measure specification or standard that may result in an environmental effect (OECD: Environmental effects, environmental quality standard). It can also be a deviation in management procedures stipulated in the agreed-upon management plan. This is not noncompliance of a regulation. The following International Organization for Standardization document provides further background on the subject.

Key reference

ISO. 2006. Conformity assessments – Requirements for bodies providing audit and certification of management systems. International Standards Organization, ISO/IEC 17021:2006(E).

Once an audit is completed, documented nonconformities are analysed to determine their cause and to identify corrective actions (ISO 14050:2009: Corrective action) to prevent their occurrence in future. Once corrective actions have been identified, additional documentation and follow-up evaluations are required to ascertain that the corrective actions have been effectively implemented.

Audits and corrective actions are essential elements of the feedback loop regarding the performance and effectiveness of implemented management plans and may trigger a review of the management plan (ISO Guide 73: Risk treatment). Such reports are key communication (ISO Guide 73: Communication and consultation) tools for the governance of the management area and for reporting to stakeholders and the public. Publically funded governance structures must be informed as to the performance of the management plan in order to justify public investments and demonstrate how legislative intent and ecosystem management outcomes are being met. Stakeholders (ISO Guide 73: Stakeholder) that implement management measures have to be informed of their performance in order to justify their investment of human and financial resources. For public reporting, report cards may be used to summarize the technical aspects of the report.

Further reading

Canada. 2004. Performance Audit Manual. Office of the Auditor General. 134 pp. Available online at http://www.oag-bvg.gc.ca/internet/docs/pam_e.pdf.

CESD. 2009. Chapter 1: Protecting Fish Habitat. Report of the Commissioner of the Environment and Sustainable Development 2009. Cataloque No. FA1-2/2009-1E. Available online at http://www.oag-bvg.gc.ca/internet/English/parl_cesd_200905_00_e_32510.html#hd5c.

CESD. 2011. Chapter 3: An audit of Enforcing CEPA; Chapter 4: A Study of Managing Fisheries for Sustainability. Report of the Commissioner of the Environment and Sustainable Development 2009. Catalogue No. FA1-2/2011-2-0E-PDF. Available online at http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201112_e_36027.html.

KnowSeas. 2010. Deliverable 6.1 Conceptual design of the Ecosystem-based Management System (EBMS). European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number 226675.

Wilson, P., and Pearson, R. D. 1995. Performance-based Assessment: External, Internal, and Self-Assessment Tools for Total Quality Management. ASQC Quality Press, Milwaukee, WI, USA. 202 pp.

Quality assurance checklist

- What is the formal approval process to initiate an audit and implement a corrective action plan?
- Who is responsible for the delivery of the audit programme?
- What is the scope of the audit criteria regarding the roles and responsibilities of the audit and documentation required?
- Who is responsible for preparing the audit report and responding to the findings?

8.8 Periodic review

(ISO Guide 73: Review)

Operating within the principles of adaptive management, periodic reviews of existing management plans and their implementation are necessary as new knowledge, drivers, or development comes to light. The reviews also consider the information from performance and effectiveness audits (ISO Guide 73: Risk management audit) and the state of the environmental effects (ISO Guide 73: Monitoring, OECD: Monitoring). It ascertains if the risk management plan is meeting the ecosystem management outcomes. The reviews determine if there is a need to trigger a review of the ecosystem-based management context starting a complete risk management process (ISO Guide 73: Risk management process). Not intended to be a comprehensive list, reasons for initiating a new risk management process could include the following.

- Recent knowledge regarding the ecosystem (OECD: Ecosystem, ecosystem services), social, cultural, and economic components and processes (OECD: Environmental services) have identified new vulnerabilities (ISO Guide 73: Vulnerability) that should be considered to achieve the ecosystem management outcomes.
- New technologies or management strategies are available to better manage the risks attributed to environmental effects.
- New drivers or existing drivers are generating new pressures and environmental effects not anticipated in the original risk management process (ISO Guide 73: Risk management process).
- Changes have occurred in the legislative and regulatory instruments or governance mandates.
- Changes in public policies have identified the need for new ecosystem management outcomes.

Although such reviews may occur several years after the implementation of the management plan, periodic reviews can occur on an *ad hoc* basis as required or have a pre-set review date agreed upon by all signatories or enshrined in law. Although performance and effectiveness audits and environmental effects monitoring may have already triggered updates to the management strategies, periodic reviews are essential elements of the quality-assurance feedback loop of any management system approach. Such reports are key communication tools for the governance of the management area and for stakeholder and public reporting. Governance bodies, stakeholders, and the public have to be kept informed of the status of the ecosystem management outcomes and the performance of the management strategies.

Further reading

Stankey, G. H., Clark, R. N., and Bormann, B. T. 2005. Adaptive management of natural resources: theory, concepts, and management institutions. General Technical Report, PNW-GTR-654. Portland, OR, US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 73 pp.

Williams, B. K., Szaro, R. C., and Shapiro, C. D. 2009. Adaptive Management: The US Department of the Interior Technical Guide. Adaptive Management Working Group, US Department of the Interior, Washington, DC.

Quality assurance checklist

- What is the schedule for the review of the plan?
- Who is responsible for initiating and performing the review?
- What is the formal approval process?

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