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A resource guide for managers

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About this document

This document is a practical guide to the responsible and effective planning of offshore geophysical surveys and other forms of environmental imaging. It will be useful for both understanding the impacts of imaging surveys on managed resources and planning future activities.

To increase consistency in both the evaluation and mitigation of potential effects, the process described in this document involves a systematic evaluation of activities and potential impacts, recognizing that these may impinge on multiple regulatory jurisdictions. The focus is on marine mammals, which, in addition to their being high-order predators in most marine ecosystems, are afforded relatively strong regulatory protections in many parts of the world. Nonetheless, the elements of this planning tool are applicable and adaptable for application where the focus is on any locally important species, e.g., fishes, sea turtles, seabirds.

The intended audience includes industry (both environmental managers and operational leads of survey activities), regulators (governmental staff responsible for the assessment of industry plans in order to ensure effective mitigation of potential negative environmental impacts), and scientists (who may provide advice to industry, government, or other stakeholders).

This is expected to be a living document, based on feedback and updates to guidelines and regulations in different parts of the world, and it has been prepared using available literature (Annex) and through direct consultation with and review by representatives of industry, government, and conservation NGOs. The document will be updated through ongoing dialogue and communication among various stakeholders, including IUCN, industry, and regulatory agencies and organisations.

EXECUTIVE SUMMARY

This document is a practical guide to responsible and effective planning of offshore geophysical surveys and other forms of environmental imaging. It offers a structured, systematic evaluation and decision-making framework for industry, regulators, and scientists. The basic elements, structure, and sequence of this framework are adapted from Nowacek et al. (2013). While the focus here is on marine mammals, this process can be applied in any situation involving protected and sensitive species (PSS).

The process presented in this document begins with pre-survey screening of proposed activities and the local environment, and then moves into a series of practices for planning, implementation, and evaluation of mitigation and monitoring activities.

Pre-survey screening

Before any practices are begun, an initial, overarching risk assessment of the general nature of the survey activity and the local environment is necessary, to help determine the scale and magnitude of effort that will be required. This involves assessing the type, scale, duration, and specifics of the proposed survey, as well as the environmental features and potentially affected species within the survey area.

Practice #1. Assess and Evaluate the Environment in the Context of the Proposed Action

Once pre-survey screening has been completed, the next step is to conduct an appropriately scaled evaluation of the environment in which the proposed survey would take place. This might involve a review of existing data, if it is a well-studied area, or additional collection of baseline environmental data, if the area is relatively unexamined. The elements of this practice include:

- **collection of baseline environmental and biological data (biotic and abiotic features of the ecosystem)**, including the identification and evaluation of multi-year data on protected or sensitive species and other species that may be impacted, ecosystem features, and physical aspects of the environment;
- **identification of proposed actions and alternatives**, including sound output parameters from seismic sources; sound propagation and exposure modeling tools, algorithms, and assumptions; and alternatives that could minimise overall exposure of PSS to sound; and
- **stakeholder engagement**, including consultation and collaboration with individuals, non-governmental organisations, or government agencies that may have an interest in or be affected by seismic activities.

Practice #2. Evaluate Risk and Develop Plans

Following from the assessment of the environment and the proposed operation conducted in Practice #1, the next step is a structured risk assessment to determine the magnitude of potential impacts from the survey activity. This elements of this practice include:

- **evaluation of risks of proposed actions and alternatives**, based on survey characteristics, and environmental and biological/ecological characteristics. This evaluation should include an exposure analysis, evaluation of potential acute and chronic effects, and an assessment of estimated response probability for affected species;
- **identification of mitigation actions**, including specific mitigation objectives, operational protocols for the detection of PSS, and training and coordination for relevant personnel; and
- **development of monitoring strategy and methods** for application before, during, and following operations. Monitoring protocols should be developed for all PSS and integrated with real-time mitigation, and should include a comprehensive reporting plan.

Practice #3. Implement Mitigation and Monitoring of Operations

This step involves implementation of the mitigation and monitoring plan developed in Practice #2. The elements of this practice include:

- **operational implementation of mitigation measures**, giving consideration to the timing of the survey and source characteristics;
- **implementation of real-time mitigation**, including written protocols and a dedicated effort by properly trained personnel; and
- **implementation of monitoring protocols with data validation and archiving**, to allow for effective post-survey reporting and evaluation.

Practice #4: Evaluate and Improve

Assessment and evaluation should begin at the conclusion of operations, with the twin aims of presenting a thorough evaluation of the efficacy of the monitoring and mitigation plan, and developing lessons learned to be incorporated into future monitoring and mitigation programmes. It is important that results and analyses from monitoring and mitigation be made available as openly as possible, to all stakeholders and interested parties. Elements of this practice include:

- **reporting on effectiveness of the mitigation programme**, including an overview of operations, effort, effective implementation of mitigation measures, any major events, initial data analyses, and short- and long-term plans for analyses;
- **review of effectiveness of the monitoring programme**, to allow for improvement in future mitigation methods; and
- **prompt analysis and availability of results**, to help inform future risk assessments and mitigation and monitoring efforts, and to identify and fill data gaps to support future activities and exploration of the ecosystem.

Introduction

This document is a practical guide for environmentally responsible and effective planning of offshore geophysical surveys and other forms of environmental imaging, particularly with respect to marine mammals, though the principles and practices can be applied to any protected and sensitive species (PSS, as defined by IUCN and/or local or national jurisdiction). Much of the focus (and examples) relates to the planning and implementation of large-scale airgun surveys, given the relatively intense, low-frequency nature of the sound source and their global use. Also considered here is the responsible planning of other forms of environmental imaging surveys (e.g., certain types of multi-beam sonar systems) that are often associated with offshore exploration and energy production or undersea bathymetry mapping. This document provides a structured evaluation and decision-making framework that is intended to complement other existing environmental best practice recommendations developed by industry and others (e.g., IAGC, IPIECA, JNCC). Its complementary value comes from the fact that it has been developed primarily by scientists familiar with many of the environmental and biological considerations that are key to monitoring and mitigation.

A responsibly operated survey gives due consideration to the fact that business, social, and environmental priorities can be in conflict. A responsible operator will perform the appropriate risk assessments to ensure a proper balance between risks to the habitat and benefits to a wide range of stakeholders, in an open and transparent manner. The framework and recommendations presented here are intended to facilitate consistent, effective, and efficient planning, conduct, and evaluation of surveys in terms of potential environmental impacts. All stages of operations (before, during, and following) are evaluated within a risk-assessment-based iterative process. The advice is based on significant recent progress in scientific research and direct observation of operations and associated monitoring and mitigation over several decades of geophysical and other industrial surveys. Increasingly complex regulatory evaluation, sustained research effort (including evolving consideration of the biological significance of disturbance and potentially interacting or chronic effects), and improvements in technology provide the basis for a logical and structured approach to the responsible operation of high power marine seismic surveys and other forms of imaging.

The conceptual foundation for this guide is derived from Nowacek et al. (2013), who laid out the elements of responsible conduct of seismic surveys, with emphasis on environmentally sensitive areas. As underscored there, not all of the individual sub-elements of the broad steps identified below will necessarily be appropriate for every survey. This document describes an ideal situation, where there is sufficient advance planning to conduct ecological surveys prior to even beginning the risk assessment and permitting process. While this may not always be possible or may not be required under present environmental legislation, the ideal remains, and a precautionary approach to scientific uncertainty is warranted as part of any risk assessment.

It is recognised that the practical implementation of these principles will vary by situation, given the great diversity of environmental, operational, and regulatory contexts in which seismic and other environmental imaging surveys take place around the world, and the associated great variation in estimated risk. Adaptation to particular local scenarios and applicable regulatory requirements, however, does not remove the importance of following the logic of planning, risk-assessment evaluation, implementation, and subsequent analysis to conduct surveys responsibly and to inform future operations such as those described here. This document proposes an iterative risk-assessment-based evaluation, beginning with pre-survey screening of important factors related to sound-sources, marine mammals, and the environment at a relatively broad scale, followed by a series of practices associated with planning, implementation, and evaluation.

The basic elements, organisation, and recommended sequence of the practices described here are adapted from Nowacek et al. (2013) and are summarised in Figure 1 and elaborated upon in Figure 2. The intent here is to provide greater detail concerning many of the envisaged processes, as well as current and comprehensive references for region-specific operational practices, regulatory requirements and criteria, data analysis and archiving, and other practical guidance for planning. The Annex (which is hosted online by IUCN and will be regularly updated) is an additional resource to complement in greater detail some of the matters to be considered when creating a survey plan. The Annex lists relevant documents in a literature database; in addition to primary scientific literature, it includes regulatory and statutory literature to assist operators and managers.

The use of assessment and planning tools available to managers is encouraged, and detailed examples are provided. The kinds of tools available to understand and monitor both baseline behaviour and exposure and responses of animals in the seismic survey theatre (e.g., passive acoustics, sound propagation modeling, vessel tracking methods) have matured significantly over the last decade. Similarly, the methods for sampling and analysing the behaviour of animals have developed significantly (e.g., integration of acoustic and visual sampling, remote tracking using tags). Lastly, analytical tools for assessing impacts (e.g., aggregate noise exposures), including cumulative impacts, are increasingly robust and accessible. While plenty of challenges remain (e.g., 'negligible impact' for noise has not been broadly or consistently defined), analytical frameworks have been published (e.g., Fleishman et al. 2016) and data from monitoring and mitigation programmes, such as those described here, can be incorporated into them.

Risk assessment is a common practice in many aspects of the energy industry. The approach to environmental risk assessment described here is simply another such process. While such procedures are already used to some extent by some industry operators (e.g., OGP & IAGC 2011 in the Annex), the intent here is to recommend a structured and consistent, yet adaptive, approach with a biological perspective that can be broadly applied. Among the kinds of questions evaluated within such an environmental risk assessment are: What animals can be expected to occur in the area during the activity? What are those animals' food source(s)? and How can potential effects be mitigated?

This document demonstrates the need for and feasibility of a comprehensive risk assessment, implementation, and self-evaluation environmental programme, recognizing that environmental imaging projects are multi-faceted, and environmental aspects are just one component of the overall project. A company's success is primarily measured in financial terms. From a company stockholder viewpoint, responsible environmental planning makes good business sense. Companies that are environmentally responsible are more competitive, have less risk and are viewed more favourably by the public, regulators, and other stakeholders. Given that each imaging project is unique, this guide does not presume to estimate the budget implications of responsible environmental planning. However, it does encourage the planning of effective and responsible surveys to be considered equal in importance to other project elements, particularly with regard to areas that are often overlooked (e.g., analyses of monitoring and mitigation results). By integrating responsible environmental planning into the normal project planning process, industry and the environment stand to benefit greatly over the long run.

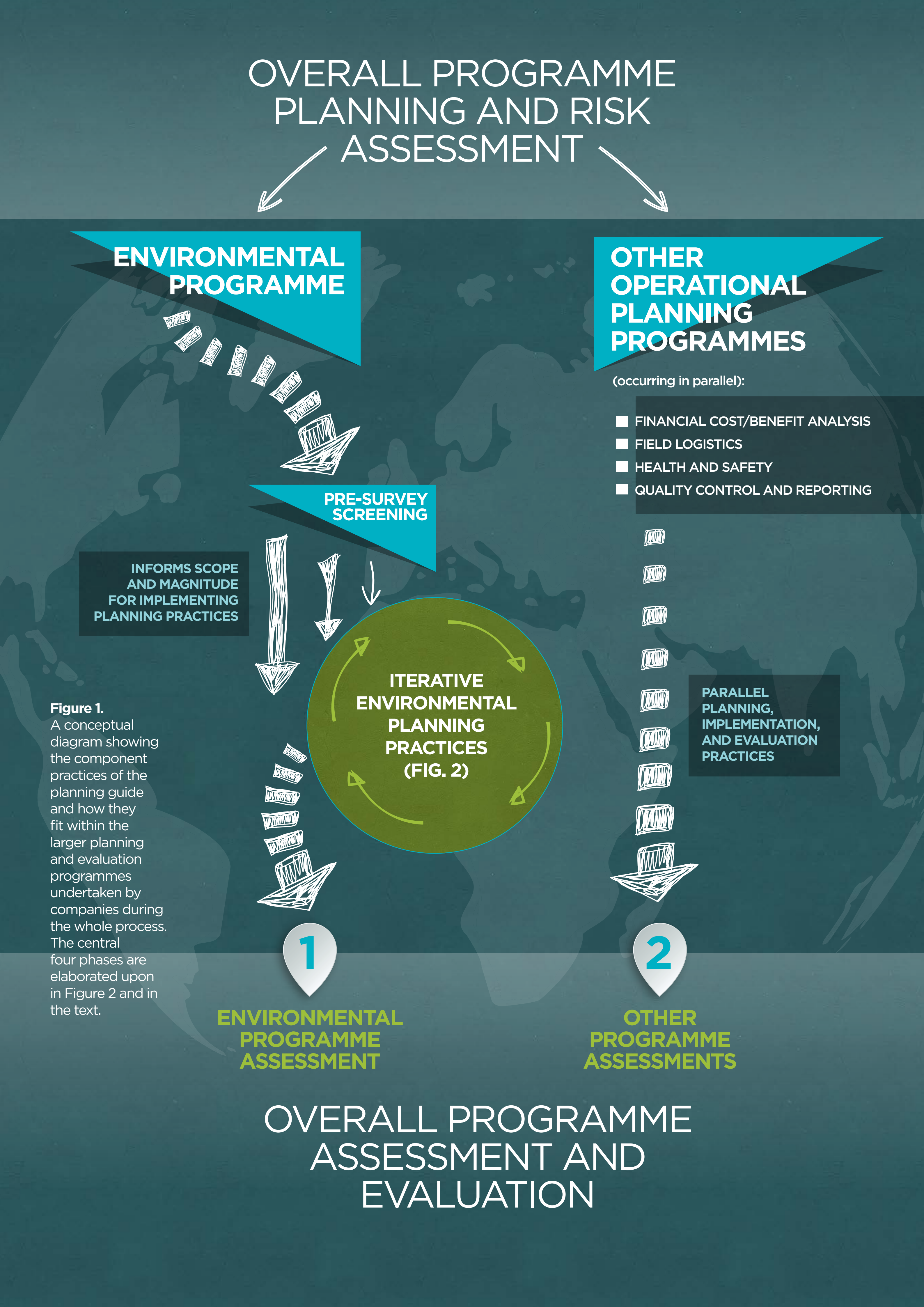

Figure 1. A conceptual diagram showing the component practices of the planning guide and how they fit within the larger planning and evaluation programmes undertaken by companies during the whole process. The central four phases are elaborated upon in Figure 2 and in the text.

ELEMENTS OF GOOD PRACTICE WITHIN EFFECTIVE PLANNING PHASES

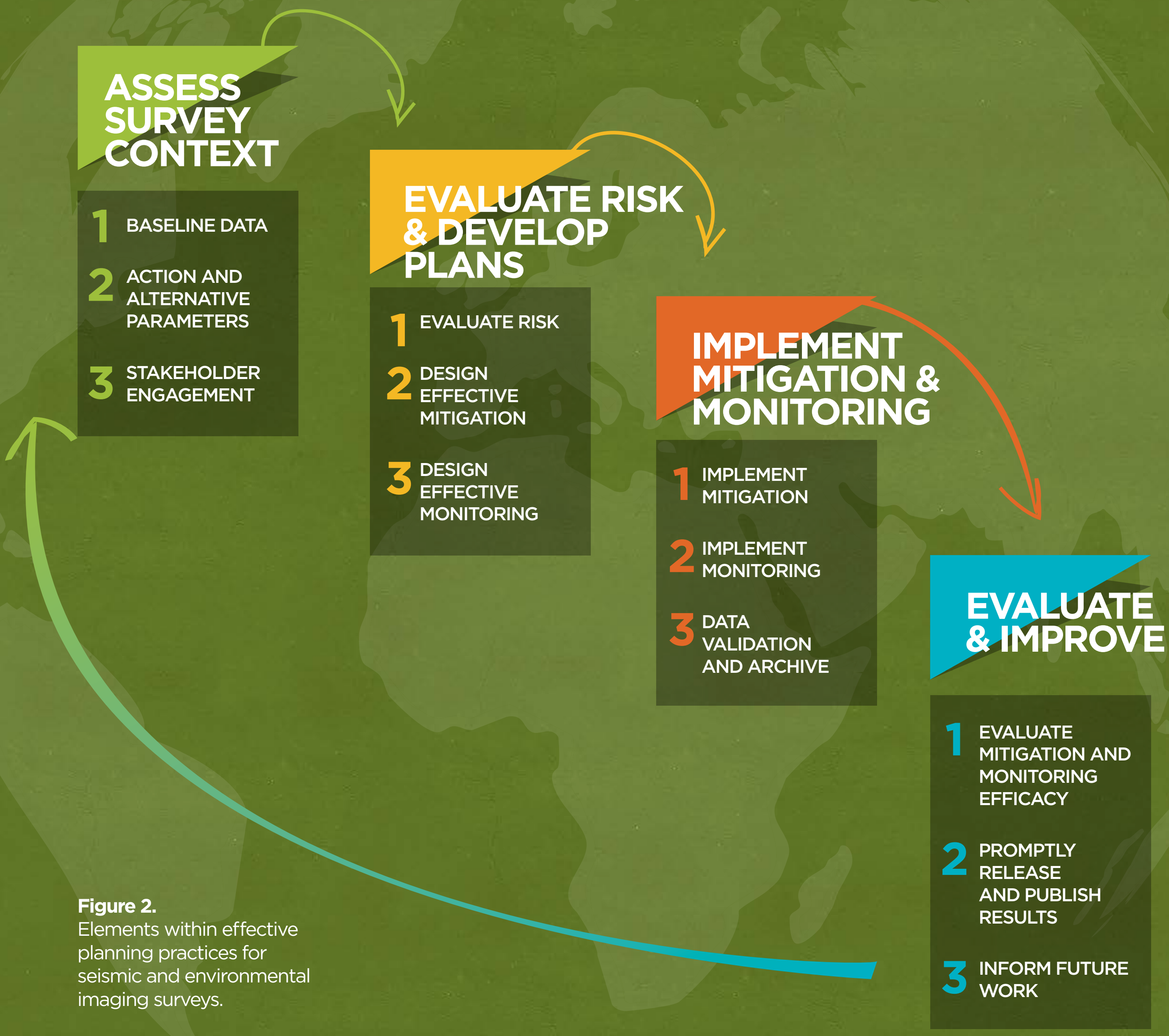

Figure 2.
Elements within effective planning practices for seismic and environmental imaging surveys.

Pre-Survey Screening

Rationale

The iterative practices for effective planning strategies described below are comprehensive and cover the full range of possible tools that could and, in some cases should, be applied when responsibly planning and legally conducting offshore geophysical or other types of environmental imaging surveys. It should be recognised that there is a wide range of conditions affecting which practices should be implemented and to what degree. There is also a range of activities that may fall within the definition of seismic or offshore environmental imaging surveys, and there are many conditions that determine the relative level of risk and, thus, the type(s) and extent of mitigation and monitoring. Contextual factors that will help determine what types and levels of mitigation and monitoring are appropriate include the type and timing of the survey, the environment in which it is to occur, other activities in the area, and the species potentially affected (see Table 1 for assessment of available baseline data).

An initial, overarching risk assessment of the general nature of the survey activity and environment is recommended. This will be important for determining the relative breadth and level of effort required to implement the practices described below. How the overall effort is structured and implemented will vary depending on the action, proponent, and regulatory situation.

Table 1. Guideline for assessing the type and extent of available baseline information. The three categories of baseline information needed include: occurrence and distribution of protected and sensitive species (PSS), the physical and biological environment, and current and future exposure of the area to human activities. Types and sources for those data are suggested, though this is certainly not an exhaustive list. Finally, a tiered system is suggested with example references to assist planners in understanding their relative preparedness with respect to baseline data.

Baseline Data – guidelines for use in assessments

Areas of Needed Baseline Information and Associated Data Types*:

I. **Protected and Sensitive Species (PSS) occurrence and distribution**
- Aerial/vessel/shore-based visual surveys
- Passive acoustic monitoring

II. **Physical/biological environment**
- Currents, ice cover, bathymetry, prey fields, sediment type

III. **Current and future human activities (in addition to survey activities)**
- Other oil and gas exploration and development
- Shipping traffic, fishing, construction, naval activity, acoustic research activities

**Note: Data sources can include existing literature, reports, analyses from previous surveys, or other information available through open-access channels.*

Baseline Data - Tier 1	Tier 2	Tier 3	Tier 4
No available data or very limited short-term data	Short-term data for 2 or more data sources	Multi-year data for 1-2 data types (e.g., Reeves et al., 2014); additional data of other types	Multi-year data for most data types (e.g., Muir et al., 2016)

Survey Type

The nature of the survey activity is clearly a major consideration in determining the potential environmental risk associated with it. Key elements include at least the following:

- whether the survey is an isolated event or part of a broader series of surveys or development in an area;
- geographic scale;
- total survey duration, season, and daily duty cycle;
- the number and types (e.g., airguns, multibeam imaging sonars) of sound sources to be used – output characteristics of the different sources need to be included;
- extent of associated support vessels and aircraft beyond survey-specific sound sources; and
- extent of overlap with areas of economic (e.g., fishing areas) or cultural significance (e.g., subsistence harvests or areas of special interest).

Higher potential risk will likely be associated with surveys and related activities that are:

- repeated or include broader-scale development (e.g., multiple operators or fields) within a defined geographic area;
- concentrated in sensitive habitat areas;
- continuous and/or overlapping with biologically important periods;
- likely to include additional intense sources (e.g., scanning sonar) audible to protected species, particularly those with multiple such sources;
- associated with numerous support operations; and
- likely to disrupt economic and culturally significant activities.

Physical Features and Human Activity Within Operational Area

Similarly, features of the environment in which surveys are being contemplated may strongly influence the associated potential risk as well as the monitoring and mitigation plans. These features include (at least) the following:

- whether survey operations are frequent or occasional within the operational area;
- the extent of other survey operations or activities (e.g., fishing, shipping) in the survey area;
- whether operations will occur in shallow or deep water;
- bathymetry and complexity of the bottom;
- aspects of habitat relevant to potentially affected species (e.g., prey distribution); and
- ocean and weather conditions during the time window of the survey.

Surveys in areas where industrial and other survey activity is rare may pose a greater risk of some acute, short-term effects (e.g., behavioural response) than surveys in regions where such activities are common. While surveys in areas where many other activities also occur may have less associated risk in terms of short-term disturbance (e.g., animals may display some tolerance for surveys), they may increase the potential for chronic impacts. Surveys in shallow areas may interact with numerous species, but those that occur around shelf breaks, seamounts, or other aggregating features, including those that aggregate prey, may have higher potential risk and require associated mitigation and monitoring. Lastly, the ocean conditions (e.g., temperature, bathymetry, substrate composition) can dramatically affect sound propagation.

Potentially Affected Species

The distribution and density of potentially affected species is another key consideration when evaluating potential risk. This is obviously influenced strongly by the environmental features identified above, but also by other species-specific features such as:

- whether the species or populations present is/are threatened or endangered;
- whether the species is/are resident or transient during the survey period;
- whether the survey activity is to occur during biologically important periods, e.g., breeding or feeding; and
- the hearing capabilities and sensitivity of the species relative to survey sound sources.

Higher potential risk from a conservation perspective will likely be associated with surveys in areas inhabited by threatened or endangered species. Higher risk may also be associated with scenarios where species occur for some biologically important reason (e.g., calving, mating), where species particularly sensitive to disturbance are present, and where species occur that hear and use sounds of similar frequencies to those produced by the surveys.

Overall Evaluation

The initial evaluation and screening process presented here describes an ideal situation, where there is sufficient advance planning to conduct ecological surveys prior to even beginning the risk assessment and permitting process. Furthermore, many of the environmental laws that regulators work under require only that the best available science is used and the relevant uncertainties are noted and addressed in some way in the documentation for decisions. Each survey and operational environment will have unique aspects, and therefore it would be unrealistic to envisage a strictly formalised risk assessment process that incorporates all of the above considerations while fitting each unique condition.

Nevertheless, an initial evaluation of the operational, environmental, and biological factors identified above, conducted within the context of existing environmental impact assessment and planning processes, is always desirable. The scale and magnitude of the practices (described below) to be implemented will depend on the outcome of this assessment. Where factors consistent with relatively high potential risks are identified, a more aggressive and comprehensive approach to the environmental practices process described here should be taken, and this may include considerations of seasonal or area-specific restrictions or modifications of survey operations.

Practice #1:
Assess the Environment in the Context of the Proposed Action

Rationale

Once a thorough pre-survey screening of operational, environmental, and biological factors has been conducted to evaluate overall potential risk, the next step, prior to any detailed operational planning, is an appropriately scaled evaluation of the environment within which the proposed action would occur. It is important to recognise that these initial steps described for Practice 1 do not constitute a detailed evaluation of environmental risk from a specific proposed activity. Rather, they represent an initial evaluation of the environment in which the survey is expected to occur and the types of survey components that would be required in order to conduct a detailed analysis of environmental risks. The evaluation process envisioned here includes this initial consideration of the broader environmental issues, given survey parameters, but also includes a detailed and structured biological and ecological assessment once a specific plan of operations has been developed (Practice 2).

In well-studied areas where operations and/or research programmes have previously occurred, the detailed assessment will include the identification and evaluation of existing data to be used to build the assessment, as well as any ongoing data collection. In relatively unstudied areas, where seismic surveys are now increasingly occurring, this may require additional and, in some cases, sustained (multi-year) collection of baseline environmental data to inform meaningful risk assessment and operational monitoring and mitigation.

Managers need to recognise that good baseline environmental data are required for effective risk management. For particularly sensitive areas (e.g., habitats hosting threatened or endangered species), sustained monitoring (e.g., multiple seasons or years) may be needed prior to operations (see Table 1 for guidance in assessing the level of available baseline data, and Case Study 1 for one approach to amassing baseline data). In parallel, this initial planning and assessment stage requires a rigorous evaluation of the nature of proposed operations. Ideally the relevant operational parameters identified below will be described and presented using standardised metrics and descriptions.

An assessment of a proposed action and its potential impacts on specific environments can be referred to as an environmental assessment, environmental impact assessment, environmental impact statement, or environmental and social impact assessment. The concept of environmental impact assessment (EIA) arose during the 1960s, a time of rapid industrial expansion coincident with rising awareness of how development can threaten wild living resources. Such an assessment is intended to ensure that those who make decisions on whether and how a development project can proceed are well-informed about the likely consequences and severity of risks involved. Operators who are planning activities often face requirements to prepare assessments for submission to regulators. Since first being codified in the United States by the 1969 National Environmental Policy Act (Caldwell 1988), the generic EIA process has been adopted and incorporated into the legal and regulatory systems of many countries (e.g., *U.S. Federal Register*, 43 FR 55994, 29 November 1978; European Union Environmental Assess ment, *http://ec.europa.eu/environment/eia/home.htm*; New Zealand Department of Conservation, *www.doc.govt.nz/conservation/marine-and-coastal/seismic-surveys-code-of-conduct; and see Annex)*. This guide is intended to complement and improve the quality and long-term utility of the resultant monitoring and mitigation programmes, with particular emphasis on areas or scenarios where existing data are limited. Another important set of guidelines for offshore industries that use seismic sources comes from the International Finance Corporation Performance Standards and associated Environmental, Health & Safety Guidelines. As part of Performance Standard 6, Guidance Note 9 states, '*As part of the ESIA (Environmental and Social Impact Assessment), baseline studies should be conducted for the relevant biodiversity attributes and ecosystem services.*' (see Annex for links and references to the IFC Performance Standards).

Elements of Good Practice

A. Collection of baseline environmental and biological data – biotic and abiotic features of the ecosystem

This section specifies the types of information required to complete a robust evaluation of potential effects from a survey, given both what is known about the physical environment (as it affects the nature of surveys and aspects of sound propagation) and what is known about the animals likely to be present. In situ measurements of the biological environment are needed, along with sufficient characterisation of sources of natural variability, e.g., seasonality, habitat use patterns.

At the start of planning for a specific survey, multi-year data on the general characteristics and natural variability of the relevant biological and ecological systems of the study region need to be identified and evaluated (Table 1). If necessary, the gathering of such data should begin immediately after the decision has been made to proceed with the project. At the very least, basic information on species of concern needs to be collated and evaluated, based on either direct observations in the survey area or reasonable expectations inferred from observations in similar areas and situations. Often, the collation and presentation of such information takes place as part of the preparation of an EIA. However, this initial review and analysis is frequently less rigorous, and consequently less useful, than it could be. For example, just knowing that a species or population of concern occurs in or near the action area is not sufficient. Particularly when a survey has been judged during pre-survey screening to have relatively high potential risk, a thorough understanding of seasonal occurrence and animal density, behaviour, reproduction, foraging, and habitat use is important to guide planning and mitigation design. Some operators have taken this need for baseline data very seriously (see Case Study 2). Also, information on physical properties of the area (e.g., water temperatures, timing of formation and recession of sea ice, seasonality and severity of storms) and how these influence the life history and behaviour of the animals (e.g., calving/pupping, mating, foraging) may indicate that their exposure to seismic survey operations can be greatly reduced or eliminated simply by adjusting the timing of the survey(s).

Priority information needed to proceed:

- Quantify presence, distribution, seasonality, behaviour, other stressors, and habitat use of the area by PSS, using all available data sources (including unpublished data, but with transparent and consistent approaches to validation and referencing).
    - Initial information can be gathered by thorough literature searches for information on PSS and the local environment. If the necessary information is lacking or insufficient, information from other areas on the PSS and/or closely related species can be used to supplement what is known about the species or population of immediate interest. For example, information on bowhead whales (*Balaena mysticetus*) could be relevant if the survey area includes right whales (*Eubalaena spp*) habitat. Existing information is helpful or necessary for building a baseline and will also guide collection of additional data.
- Identify ecosystem features (e.g., prey resources) that may be particularly sensitive to acoustic disturbance and/or are key components of PSS habitat.
- Determine physical aspects of the environment that are likely to influence how the survey is conducted or the activities of the PSS (Most, if not all, of these are likely to be considered as part of survey planning, but it is important to consider them in the context of mitigation and monitoring for PSS.). These physical aspects include:
    - water temperatures and other ocean conditions (e.g., ice formation) as they affect operations and occurrence of PSS;
    - bottom type and bathymetry as needed for acoustic propagation modeling; and
    - tides, particularly as they can affect the survey design or timing and thus the timing, nature, and frequency of interactions with PSS.

Information that is desirable:

- Distribution and habitat use patterns for all species, including non-PSS, that are likely to use the area during the survey and could be impacted (e.g., fishes, turtles); such information may indicate strategies for reducing risks to non-PSS without affecting operations.

> **The information collected during this practice will also be used for:**
> 1. Risk assessment (Practice 2.A)
> 2. Mitigation design (Practice 2.B)
> 3. Monitoring programme design (Practice 2.C)
> 4. Assessment of mitigation efficacy (Practice 4.A)

B. Identification of proposed actions and alternatives (all stages and realistic alternative strategies should be described, regardless of economic feasibility)

This section identifies specific needed information concerning survey elements, including options that would likely bring differential risks to the environment. The purpose of Practice 1 is to evaluate the options, in a relatively broad way, in order to specify survey aspects and locations (to the extent there are options), thereby enabling (in Practice 2) a robust evaluation of potential effects from a survey, given what is known both about the operation itself and the PSS that could be affected. Some of the information specified here is similar to that required in Practice 2 and would be applied there for the survey elements or options that are proposed and explicitly evaluated in terms of potential risk.

1. Describe sound output parameters from seismic source, vessels, etc., including:

- number and size of airguns in the array or, in the case of some other acoustic source, the detailed source parameters;
- source modeling, e.g., directivity, total source power; and
- total output (number and activity level) of all vessels involved in operations.

2. Identify sound propagation and exposure modeling tools, algorithms, and assumptions, including:

- elements for modeling, such as:
  - knowledge of bathymetry;
  - data on water temperatures and sound velocity profiles at the relevant time of year; and
  - source characterisation for all sound sources sufficient for incorporation into the model.
- elements of animal movement, including clearly specified species-specific assumptions regarding aversion, flight, attraction, etc.

3. List and evaluate alternatives that could minimise overall exposure of PSS to sound, particularly identifying ways to reduce the overall survey footprint through analysis or re-processing of available data. Options to consider include:

- seismic source type – consideration of existing and new geophysical survey technologies (e.g., marine vibroseis) that may have reduced acoustic output levels is encouraged;
- seismic source size – source power scaled appropriately for required substrate penetration;
- multi-client surveys – in areas where several companies are operating, significant cost savings and reduced environmental impacts can be realised without compromising desired data types and quality; this practice is becoming more common around the world;
- survey area size – boundaries set to include only areas where data are essential;
- modifications of survey area, timing (e.g., time of year), and duration to avoid or reduce extent of operations within key PSS habitat or during particularly sensitive periods for PSS;

- minimizing the use of the loudest sound sources during periods of low visibility (e.g., night, fog), while balancing this with the overarching objective of reducing overall survey duration;
- consideration of passive (e.g., listening for animal vocalisations) and active (e.g., using a controlled sound source to discover the presence of animals) acoustic systems for both mitigation and monitoring;
- consideration of aerial surveys (manned and unmanned) for PSS, in conditions where assessed risk of the survey and the probability of detecting PSS are both relatively high; and
- consideration of new and evolving technologies such as thermal and satellite imaging for animal detection, primarily for mitigation but also perhaps for monitoring under appropriate conditions.

C. Stakeholder engagement

As indicated in Figure 2, some companies conduct separate risk assessments for potential social impacts stemming from their operations. If not already incorporated or required under EIA practices, seismic activities should become an important part of the social risk assessment component, to ensure all stakeholder interests are properly addressed. Stakeholders are groups – individuals, non-governmental organisations, or government agencies – that have an interest in or are potentially affected by the company's activities. While the companies themselves are ultimately responsible for integrating the requirements of the survey and associated environmental requirements, engaging stakeholders at the earliest possible stage can be critical for the success of a project. From government regulators to NGOs focused on PSS in the area, these groups and individuals need to be engaged so that they understand the real and potential impacts of the activity and are aware of one another's interests and concerns. Stakeholder engagement is also important for understanding how local communities value and use natural resources, e.g., local fishing or nature-oriented tourism. Stakeholder engagement is critically important in terms of responsible planning (For more details on ideas and guidelines related to stakeholder engagement, see the following key resources already available on this subject – e.g., ARPEL 2011, IOGP 2014, IFC 2007.).

No two seismic surveys are identical in terms of area, source size and power, animal species present, animal distribution and density, water depth, duration, distance from shore, etc. Consequently, there is no single standard protocol suitable for planning every survey. Instead, a tailored suite of mitigation and monitoring measures can be selected for each seismic programme and included in a programme-specific mitigation and monitoring plan. For the best outcome, responsible operators often choose to develop their plans in a broadly collaborative manner, led by company representatives but with meaningful input from a range of stakeholders. One important element that requires agreement and often significant discussion is that of exposure criteria. The development of operational rules for acceptable exposure of animals requires input from stakeholders, e.g., how to implement specified criteria from the relevant regulatory agency. These exposure criteria, as well as all other elements of a mitigation and monitoring plan, are discussed under Practice 2, below.

Practice 1: CASE STUDY

Baseline monitoring and stakeholder engagement – Shell programmes in Alaska

Key elements of Practice 1 include stakeholder engagement and the systematic collection of baseline environmental and biological data for survey and development areas. These fundamental components of effective planning to identify important biological elements of the affected environment and key parameters of proposed surveys, and to encourage companies to work openly with local groups and people, have been addressed with widely varying success in previous surveys.

One recent example of an integrated industry exploration programme that successfully implemented these measures responsibly is the marine mammal monitoring and mitigation program developed and implemented by Shell in the Chukchi Sea[1]. Building on earlier efforts in the Alaskan Beaufort Sea, Shell developed a fully integrated and comprehensive planning, implementation, and evaluation programme that included comprehensive and systematic calibrated sound source verification procedures for all survey sound sources. These data, collected using controlled measurements, provided detailed and precise information on the sounds that would be introduced into the environment during operations, and their propagation over distance. Although environmental impact assessment (Practice 2) requires this information, it is often lacking.

Significant effort was also dedicated to designing basic monitoring of the natural and biological elements of the survey areas. These efforts included numerous years of dedicated monitoring with specified key species and objectives, using a combination of visual survey, acoustic monitoring, and environmental measurements. Baseline monitoring was conducted through a number of mechanisms, including contractors directly funded through Shell, involvement and support for joint monitoring efforts with other industry operators to better understand the broader region beyond the immediate survey area, and support of baseline monitoring programmes in partnership with local communities and native peoples[2]. Shell approached the requisite baseline monitoring using robust methods and specified monitoring objectives over multiple years preceding operations, working with a variety of stakeholders, including private sector and academic scientists, industry partners, and local people. This programme was thus able to accomplish both robust baseline data collection and transparent stakeholder engagement simultaneously.

1 http://www.nmfs.noaa.gov/pr/permits/incidental/oilgas/shell_2015_revised4mp.pdf

2 http://www.north-slope.org/departments/wildlife-management/nsb-shell-baseline-studies-program

Practice #2: **Evaluate Risk and Develop Plans**

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Rationale

As discussed above, comprehensive implementation of environmental plans for operations requires information on baseline features of the environment, potential disturbance from survey operations, and aspects of the proposed operation. Given sufficient information about the environment (e.g., distribution and behaviour of key species) and the nature of the proposed operation (e.g., sound source parameters, survey duration, and spatial distribution), a structured risk assessment of potential effects should be undertaken (rather than a more binary or "threshold-based" determination as required in some jurisdictions, notably the United States).

This assessment should explicitly consider the direct physical and behavioural responses to the proposed survey activities by the focal species. Recent scientific advances in ways to evaluate how sounds from a variety of sources, including seismic surveys, affect the hearing and behaviour of marine mammals have greatly improved our ability to assess potential disturbance. Increasingly sophisticated analytical approaches to estimate effects apply probabilistic functions and incorporate features of exposure context, such as relative range and motion of sources, that go beyond simply sound exposure level, (see Annex 1 for examples).

Using the output from Practice 1, a structured evaluation of potential risks can be conducted that considers the magnitude of predicted physical and behavioural effects of the operation, as well as other human activities, within the context of population characteristics and species life history. This allows assessment of risks in terms of biological significance, rather than as a simple accounting of the animals predicted to experience physical injury or disturbance. Furthermore, the aggregate, synergistic, and cumulative effects of proposed operations within the context of other human activities and broader environmental issues (e.g., climate change) can be considered. Species-specific assessed risk can be evaluated along with other relevant parameters, such as population status and trends, all in the context of locally applicable regulations and social needs, to develop meaningful monitoring and mitigation objectives and strategies. These processes are most effective when open and transparent, and include measurable variables that can be used to evaluate implementation (in Practice 3) and provide the basis for informed assessments of future operations (in Practice 4).

Elements of Good Practice

A. Evaluation of risks of proposed actions and alternatives

Among the most important aspects of the overall process is a structured, systematic method for evaluating the risks of survey operations. There are, as mentioned above, some existing industry practices that use such an approach. The probabilistic framework described here is sufficiently graded in terms of output evaluation to generate relative (not binary) assessments of risks, given what is known or estimated about the area and the proposed survey features. Based on those assessed risks, measures can be identified that can ensure, through monitoring, that they are anticipated and acceptable, and that mitigation is used if necessary. As noted above, the concept of risk assessment is applied in many commercial decisions and in health and safety programmes by the E&P industry for offshore operations. This concept is increasingly being considered and applied around the world. The specific approach to be applied, and aspects such as regulatory definitions of potential effects to be included, may differ from location to location, but the basic elements of good practice are described below.

A quantitative risk assessment can be based on the information compiled in Practice 1.A and 1.B. Additional caution may be required where necessary information is lacking or uncertainty is relatively high. However, reasonable efforts may be used to extrapolate available direct measurements to identify risks and help define appropriate monitoring and mitigation (Practices 2.B and 2.C). In some cases, directly applicable data sources can be consulted, and in some instances companies have actually taken the time and effort to collect their own data on impacts in advance of the survey, as well as during and after it (see Case Study 3). The evaluation procedure envisaged here is meant to be comprehensive yet practical. Elements of the analytical process should include:

Example input variables

- Survey characteristics (from Practice 1):
  - proposed geographical area, including detailed spatial distribution of survey effort;
  - total proposed duration and timing (season); and
  - sound source characteristics (output levels, frequency spectra, directionality).
- Environmental (non-biological) characteristics:
  - depth and bathymetry of proposed survey area (including quality of these data);
  - sound velocity profiles typical for the areas and times proposed;
  - sediment composition and other bottom characteristics (for use in acoustic propagation models);
  - presence of other survey operations and general human disturbance in the survey area; and
  - typical weather, oceanographic, and day length conditions for the operational period (as they could affect monitoring and mitigation efficacy).
- Biological/ecological characteristics:
  - distribution and density of key species present during the survey period. A sufficient body of baseline data is required to understand the anticipated distribution and density of these species and the associated variability;
  - ecological interactions and drivers influencing the distribution and density of the prey of key species (in cases where the operation is in or near a feeding area); and
  - behavioural patterns of species likely to be present during a survey related to baseline (undisturbed) and responses of those species to noise for application in animal movement models.

Exposure analysis

- Animal distribution and movement modeling including:
  - typical species presence, group structure, and baseline behaviour used to estimate expected distribution in the area in the absence of disturbance; and
  - behavioural response to noise (e.g., aversion, attraction) applied to evaluate exposure during operational scenarios.
- Acoustic exposure modeling that accounts for input variables listed above, as well as animal movement and response, to estimate average and maximum noise exposure within survey area, accounting for species-specific hearing abilities (e.g., frequency-weighting functions).

Evaluation of potential effects (exposure criteria)

Specific exposure criteria are difficult to recommend, as these values change with increasing understanding of animal responses and physiology; furthermore, the criteria and their application vary from country to country. In the absence of jurisdictional criteria, reference to published exposure criteria (e.g., Southall et al. 2007) and more recent explorations on the topic is suggested (see Annex).

- Acute effects:
  - Apply jurisdiction-prescribed noise exposure criteria to obtain a quantitative estimate of potential physical impacts on hearing (TTS/PTS), as well as physiological stress.
  - Apply jurisdiction-prescribed noise exposure criteria to obtain a quantitative estimate (preferably probabilistic) of behavioural response, if any.
- Aggregate/chronic effects:
  - Evaluate contribution of proposed survey activities in the context of other ongoing or anticipated human activities in the area.

    - Make quantitative evaluation of potential masking effects on sound communication.
    - Consider broad-scale disturbance probability, given other operations. Recent progress has been made, but assessment of these effects likely will need to be qualitative at this point, at least at some level, given current knowledge. This area will require and benefit from coordination, collaboration, and data sharing within and between industry operators, government agencies, and scientists.

Risk assessment of estimated response probability

- Evaluate risk in the context of population demography:
    - Use population model results to estimate relative (not binary) magnitude of acute effects; population models estimate the size and health of populations under varying scenarios.
    - Incorporate species-specific parameters on life history, population trend, and potential for aggregate/chronic effects (e.g., masking) within risk assessment framework.
- Conduct integrated risk assessment of potential effects:
    - Use estimated risks of acute and aggregate/chronic effects to determine overall magnitude of population level effects on survival and reproduction.
    - Account for uncertainty in key stages of this process by explicitly evaluating the adequacy of supporting information (e.g., none, indirect, direct but limited, or direct and comprehensive).
    - Apply jurisdiction-prescribed monitoring and mitigation, given the risks.

The information collected during this practice will also be used for:

1. Mitigation design (Practice 2.B)
2. Monitoring programme design (Practice 2.C)

B. Identification of mitigation actions

Using the detailed evaluation of risks to key species from survey operations, tailored mitigation measures can be readily identified. The relevant regulatory requirements for the operational area may strengthen the conclusions regarding needed action reached using the risk assessment; operators obviously need to adhere to local regulations. This section identifies and considers approaches to mitigation of potential impacts from survey operations. It takes into consideration measures being applied around the world, and thus requires substantial background work for planners (see Annex).

1. Specify mitigation objectives based on baseline data, evaluated risk of proposed actions, and applicable regulatory requirements. These may include the following:
    - Identify seasonal presence and density of PSS and modify activities accordingly to operate during non-sensitive periods.
    - Identify maximum allowable exposure levels for: (1) protected species, including more vulnerable types of individuals (e.g., mother-calf pairs); (2) any other species, i.e., allowable exposure may vary by level of regulatory protection.
    - Determine power-down and/or shut-down criteria based on maximum allowable exposure levels.
    - Identify additional mitigation requirements, including operation or non-operation of mitigation sound sources.
2. Develop operational protocols for the detection of PSS, to enable the mitigation measures. These can be integrated with monitoring and may include any or all of the following (the extent and integration of which will depend on requirements and local conditions):
    - conventional vessel- or shore-based visual monitoring;
    - real-time passive and/or (in some cases) active acoustic monitoring;
    - aerial visual surveys; and
    - infrared, night-vision and/or other technologies.

3. Ensure sufficient training and coordination, including:
   - use of experienced and well-trained field personnel; and
   - designation of an integrated command chain with a clearly identified single individual who is responsible for decisions regarding mitigation measures in the field.
4. Ensure transparency within the EIA process (as typically required) by making mitigation measures and protocols publicly available and, in specific circumstances, commissioning an independent observer to assess implementation and efficacy of plans.

C. Development of monitoring strategy and methods for application before, during, and following operations

Using the above risk assessments, and in coordination with mitigation measures and requirements, real-time and archival monitoring methods should be developed. The relevant regulatory requirements for the operational area also need to be identified and adhered to in terms of after-action reporting.

This section references and considers various monitoring approaches being considered and applied around the world (see Annex I). The extent to which and intensity with which these are required and applied will vary between individual, smaller surveys and broader survey programmes associated with major development projects. This will be determined largely within the pre-survey screening ahead of Practice 1. A note of caution here: for the best result, one should choose qualified marine mammal observers (MMOs) to conduct monitoring and mitigation operations (see reference to existing MMO guidelines in Annex). Monitoring approaches include:

1. Integrate monitoring technologies and protocols with real-time mitigation (Practice 2.B); data from these sources is also to be archived.
2. Develop monitoring methods that have sufficient power and yield sufficient information to:
   - detect changes in key baseline environmental parameters, given natural variability (Practice 1.A) and thereby assess impacts on biota, particularly PSS and/or sensitive populations;
   - ultimately, use monitoring data to evaluate efficacy of mitigation measures (Practice 2.B);
   - address data and information gaps; and
   - contribute to long-term baseline monitoring to improve understanding.
3. Develop operational archival monitoring protocols for all PSS. These protocols can, with planning, be integrated with real-time monitoring methods used to implement mitigation measures. These may include any or all of the following (the extent to which and integration of which depends on requirements and local conditions):
   - comprehensive integration of vessel-based, land-based, and aerial visual monitoring (if any);
   - archival passive and/or (in some cases) active acoustic monitoring;
   - systematic reporting of weather and ocean conditions from various sensors; and
   - systematic reporting of all operational periods with active sound sources and vessels, as well as of periods with other known anthropogenic disturbance(s) in the survey area.
4. Develop a comprehensive reporting plan for:
   - detections made using various methods in conditions where power-down or shut-down conditions both were and were not required; and
   - all observed behaviour of PSS during noise exposure and non-exposure conditions during surveys.

The information collected during this practice will also be used for:

1. Mitigation implementation (Practice 3.A)
2. Mitigation evaluation (Practice 4)
3. Future mitigation design (Practice 4)

Practice 2: CASE STUDY

Irish Government Monitoring Ahead of Exploration and Development

In 2014, the Irish Department of Communications, Energy and Natural Resources, in liaison with the Department of Arts, Heritage and the Gaeltacht (National Parks and Wildlife Service), established a significant data acquisition programme (ObSERVE[1]). The programme was designed to acquire new baseline data, with the aim of filling existing data gaps with regard to protected marine species and sites in key offshore basins. Establishment of the programme was driven by the potential issuing of licenses for oil and gas exploration, in particular in selected Atlantic Margin waters, for which there was little or no good information on cetacean occurrence throughout the year. There are two components to this work: The first is an acoustic programme involving fixed recorders and towed acoustic surveys that covers the outer continental shelf, slope, and deep oceanic Irish waters. The second component involves a series of aerial surveys for cetaceans and seabirds in different seasons. This provides an excellent example of a government taking on the responsibility of obtaining baseline data prior to the possibility of oil and gas exploration.

1 http://www.dcenr.gov.ie/natural-resources/ga-ie/Oil-Gas-Exploration-Production/Pages/ObSERVE-Programme.aspx
http://www.observe-acoustic.ie/
www.observe-aerial.ie

Practice #3:
Implement Mitigation and Monitoring of Operations

Rationale

The detailed plan for operational mitigation and monitoring based on the species – and operation – specific risk assessment is best implemented as a normal element of survey operations (see Case Study 4). Clear communication systems with sufficient back-up systems in the field are essential to ensure that required mitigation measures are consistently and effectively implemented and that real-time and archival monitoring data are collected and analysed in a timely manner.

There may be competing priorities that compromise the operator's ability (or willingness) to implement certain mitigation measures. For instance, it is sensible to preclude survey operations during night-time or limited-visibility periods, because it is difficult or impossible to detect animals visually at such times; however, this limitation may ultimately result in a substantially longer total survey duration with intermittent periods of disturbance. So, not surveying at night will increase the overall duration of the survey, though not necessarily the amount of exposure time. Modelling the overall exposure is useful to assist in the evaluation of such trade-offs. It is also important to recognise that, while mitigation and monitoring are often coupled in descriptions of procedures and in operational plans, they are by no means identical concepts. Some of the remote sensing and data collection systems used in mitigation and monitoring may of course be the same (e.g., passive acoustics, visual observations). But, while mitigation relies on monitoring methods and especially on real-time monitoring, it is also the case that monitoring on its own requires archival data acquisition and systematic monitoring of operations.

Monitoring needs to be considered as a fundamental aspect of operational objectives and protocols, particularly with methods that sample continuously, such as passive acoustics that do not depend on weather and particular ocean conditions. Sustained monitoring of operations is informed by the risk assessment conducted in Practice 2.A and directed towards key questions; monitoring also needs to follow explicit protocols and to include archiving and redundancy (back-up). In some conditions, particularly where PSS or sensitive areas are involved, consideration should be given to an independent observer to serve as a source of objective reporting on the performance and efficacy of monitoring and mitigation. An important consideration is that environmental data need to be shared by all parties and, as such, are to be considered non-proprietary. Data sharing enhances transparency and has the added benefit of reducing data collection needs by future survey operators.

Elements of Good Practice

A. Operational implementation of mitigation measures

Practice 2 incorporates aspects of mitigation that occur in the planning phase. These include giving consideration to the timing of the survey, the source characteristics, and other survey features selected to reduce associated environmental risks. However, at the operational stage, immediately before and as the survey actually takes place, further consideration of timing and source operation is needed to implement mitigation measures in real-time (i.e. in the field as activities occur).

B. Implementation of real-time mitigation

The process of risk assessment identified above (Practice 2.A) begins to reflect some of the complexity in natural systems. However, unambiguous and relatively simple mitigation protocols for initiating and suspending or terminating operations based on clear criteria and lines of communication are required for mitigation. While mitigation of direct negative effects such as physical injury or mortality is a priority, mitigation to prevent, limit, or reduce disturbance is also important.

This section (and Annex) identifies the specific elements of and approach to operational application of mitigation and monitoring. Much of this was illustrated and compared in Nowacek et al. (2013), but this document also considers what may be required in settings with less assessed risk (and perhaps smaller resources). The requisite mitigation based on local regulatory requirements, company policies for consistency with other areas, and levels of risk considered acceptable will clearly influence the nature, number, and complexity of the elements included in these protocols. Implementation of mitigation measures requires:

- Written protocols, based on anticipated scenarios, that are understood and practiced by responsible parties ahead of time:
  - Provide protocols to teams well in advance of operations, including conditions in which operations can start, can continue, or must be modified, suspended, or terminated based on criteria identified in Practice 2.B.
  - Conduct training for field personnel so that they are familiar with protocols, equipment and data recording/archiving – this may include simulations of real scenarios.
  - Clearly identify a central point of communication (commander or command centre) with authority to suspend operations (e.g. order a power-down or a shut-down).
  - Arrange for the teams responsible for real-time detection of the animals to report directly to the command centre.
  - Develop and implement clear and consistent reporting of effort and observations, including responsiveness by operators and real-time monitoring teams to shut-downs and other measures ordered by the commander or command centre.
  - Identify a designated point-of-contact within the protocols (e.g., an acoustics specialist) that can be contacted if there are in situ (i.e. real-time, in-the-field) questions regarding mitigation or monitoring that require quick responses.
  - Develop and implement a clear, structured communication and response plan for struck or stranded marine mammals. While these may represent rare or incidentally coincident events, a plan developed with local authorities will be useful in guiding response and subsequent inquiry if such events occur during a survey.
- Dedicated effort during operations:
  - Personnel with responsibilities to implement mitigation are sufficiently trained, competent, and not overly burdened with other responsibilities.
  - Personnel responsible for mitigation are given sufficient rest in between observation periods to carry out their tasks effectively.
  - If a mitigation action is called for, the central commander communicates clearly and rapidly to the operations managers to effect the measure.
  - Operations do not resume until an all-clear is given by the central coordinator based on the specified protocols.
  - Throughout operations, the central coordinator is responsible for ensuring that the reporting of observations for mitigation are being appropriately reported, archived, and backed-up to ensure a comprehensive after-action report.

C. Implementation of monitoring protocols with data validation and archiving

Monitoring methods may include a wide range of real-time and archival remote data sensing systems (as identified in Practice 2.C). Whatever the data source, the information needs to be checked for quality and then archived. Some data collection systems are implemented in operational mitigation as well as monitoring for animal presence-absence and possible responses. Other systems are intended to collect data throughout operations in order to provide an assessment and documentation of operations and the environment, including animals, during non-active and active periods of the overall survey. Monitoring protocols include both real-time and archival monitoring systems and require advance preparation, implementation with evaluation, and post-survey integration and reporting. Monitoring data are needed for mitigation evaluation (Practices 4.A and 4.B), analysis and publication of results (Practice 4.C), and future mitigation design (Practice 4.D).

Advance planning for monitoring includes:

- systematic testing and evaluation of all monitoring hardware and software systems, including testing with *in situ* power systems that may be less clean and reliable than bench conditions where they have been tested prior to operations;
- sufficient redundancies and hardware back-up systems to allow for failures;
- training and testing of real-time systems and communications for reporting results to the central survey commander; and
- detailed data archive and back-up systems for reporting real-time data and checking operability of archival systems.

Implementation of monitoring includes:

- systematic reporting of real-time monitoring results and operations, including monitoring results that trigger mitigation actions;
- systematic evaluation of performance of archival systems, e.g., archival acoustic recorders, animal sighting records;
- evaluation of noise exposure conditions relative to anticipated or evaluated scenarios (*in situ* model evaluation) – the pre-survey modeling of noise exposure conditions needs to be validated; and
- systematic evaluation of data archive protocols.

Post-survey reporting and evaluation of monitoring includes:

- ‘quick-look’ reports summarizing monitoring metadata and performance by the end of the survey – the central commander needs to evaluate this before the team leaves the field;
- redundant archives, kept at multiple sites, of all monitoring data;
- team-by-team (e.g., behaviour, acoustics) evaluation of performance relative to specified protocols;
- an after-survey report summarizing programme performance, evaluation of monitoring efficacy, and detailed reporting of monitoring results, which includes observations (and lack of observations) as well as level of effort (Broker et al., 2015). In many jurisdictions this will be assessed and reviewed by the relevant regulatory agencies. The extent to which some or all of this assessment is publicly available will have a bearing on how much confidence interested stakeholders have in the process; it is recommended that the assessment be made public.

Practice 3: CASE STUDY

Robust Integrated Monitoring and Mitigation of Surveys in the Feeding Habitat of an Endangered Species – Sakhalin Energy Investment Company

The Sakhalin Energy Investment Company (SEIC) conducted a 4D seismic survey in 2010 near the feeding grounds of western gray whales, *Eschrichtius robustus*, off the eastern side of Sakhalin Island, Russia. In an effort to minimize disturbance to the whales' feeding activity and to enhance understanding of the potential impacts of seismic surveys on gray whales, SEIC developed and implemented an extensive monitoring and mitigation plan (MMP). (This case study briefly describes some of the elements of this MMP; for more detailed information, see the peer reviewed papers that resulted from the planning, data collection and analyses associated with this MMP. These papers were published in *Endangered Species Research* as a special issue entitled 'Seismic survey and western gray whales'.)

Typically, mitigation plans involve primarily observers on seismic vessels to monitor for the presence of marine mammals in an exclusion zone, so as to prevent physical injury. Due to the protected status of western gray whales, additional protective measures were implemented. A protection zone based on a behavioural disturbance threshold of an acoustic exposure of 156 dB re μPa2 -s per pulse was applied for whales within their feeding habitat near the Sakhalin Island coast, which was defined using baseline data recorded over several years. Real-time radio-transmitting acoustic recorders deployed along this edge of the feeding area were monitored to verify the acoustic propagation models that had been run in advance and to ensure that unacceptable levels did not impinge on this critical area. The presence and activity of whales, particularly within the critical near-shore feeding area, were monitored and recorded by shore- and vessel-based observation teams. While many surveys occur well offshore, in some cases such as the SEIC survey, shore stations can be used for monitoring and mitigation efforts. Teams at the shore stations recorded both the behavior and locations of the whales, and these data were analyzed to test, respectively, for behavioral responses and changes in distribution associated with the survey. Teams on the vessels maintained the exclusion zone near the survey vessel to avoid whale injuries, and they monitored behavioral responses of whales in the vicinity of the vessel.

At the time it was implemented, the SEIC 2010 MMP was among the most extensive ever fielded for a seismic survey. As such, it has made at least three major contributions to monitoring and mitigating impacts of environmental imaging surveys: First, the planning and forethought were extensive, making use of baseline data and creating innovative strategies for ensuring that this highly endangered population would be subjected to the least possible amount of noise. Second, the implementation was meticulously conducted and provided lessons and experience that have been passed along via the third contribution, which is the follow up and dissemination of information. The efforts supported by the company and its affiliates to analyze and prepare data and information for publication has been a model that others are encouraged to follow. The survey provided valuable lessons learned, both about the MMP process and implementation, as well as the data gained about whale behavior in the presence of the survey.

Practice #4: **Evaluate and Improve**

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Rationale

Just as transparency is needed for the EIA process before development proceeds, it is essential that all stakeholders are allowed access to the results of the monitoring and mitigation programme. This gives stakeholders the opportunity to gain a clear understanding of what has been done, evaluate how their concerns have been addressed, and assess whether, in their view, an appropriate balance has been achieved between resource protection and resource use. Stakeholders expect assurances that environmental resources are being respected and not injured, and that they have been given credible, complete information on the environmental impacts of developing offshore energy resources. As mentioned earlier, it is also good for business when responsible operators learn from the strengths and weaknesses of past performance, and in so doing are able to lower their own reputational risks. Therefore, following survey operations, it is logical to re-evaluate both the potential effects of the survey and the efficacy of mitigation and monitoring measures. This evaluation should occur on short as well as long time scales, with an automatic path for incorporating new information and lessons learned into future planning and activities, particularly for more extensive survey operations and development programmes.

The assessment and evaluation should begin at the conclusion of operations, and preferably while key field personnel are still assembled. Then, throughout the data analysis and report writing phases, the assessment and evaluation should continue, with two ultimate goals: (1) presentation of a thorough evaluation of the efficacy of the monitoring and mitigation plan, including data analyses and writing of reports and manuscripts for peer review and publication (for some though not necessarily all surveys) and (2) development of lessons learned to be incorporated into future monitoring and mitigation programmes. Both of these goals depend on one critical element, and that is the collection of good data from the PSS monitoring programme and from the survey programme in monitoring the operation itself. This assessment can easily take the form of traditional post-survey reports, as well as data analyses within formal scientific studies and publications (see Case Study 4).

It is important that results and analyses from monitoring and mitigation be made available as openly as possible. Timely dissemination could be via a variety of pathways, such as online databases, reports to regulators, and/or peer-reviewed publications. In this way, the data and information acquired will contribute to a better understanding of the focal species in the context of seismic or other environmental surveys. Specific lessons- learned and recommendations for future operations should be clearly spelled out and widely disseminated for maximum impact, including an evaluation of the mitigation measures. This latter point may seem counter to the norm for industries where information is often treated as proprietary. However, responsible operators understand that the environment belongs to everyone and anything that can help other operators reduce their environmental risks is bound to improve how the entire industry is perceived globally. At the same time, a single operator that does not adhere to best practice can reflect negatively on the many operators who do.

Elements of Good Practice

A. Reporting on effectiveness of mitigation programme

As soon as possible following the conclusion of a monitoring and mitigation programme, a preliminary report should be prepared and disseminated to stakeholders. Such a report provides an opportunity to give a general overview of operations, effort, effective implementation of mitigation measures, any major events (e.g., shutdowns triggered by mitigation protocols), initial data analyses, and short- and long-term plans for analyses. Some components of the preliminary report can also be used for public relations needs (e.g., company website, press releases).

A preliminary report might include the following:

1. *A summary of mitigation measures taken* – Were mitigation measures triggered? Were any PSS encountered? If so, were mitigation triggers appropriate? This should include whether the analysts believe triggers were too sensitive, unnecessarily lengthening the survey's duration.
2. *Acoustic exposure summary* – real-time and archival effort, levels recorded, whether and how thresholds were observed.
3. *Sightings* – species of primary concern and other noteworthy organisms; observations of animals in or near mitigation areas.
4. *Behaviour* – any aberrant behaviour observed or lack thereof.
5. *Data* – plans for archiving, QA/QC and analyses.
6. *Initial conclusions/recommendations* – issues, procedures, or results that could be immediately useful, e.g., presence of PSS in the context of other operations in the area.

B. Review of effectiveness of monitoring programme

There is a natural tendency to bring a project to a close quickly then move on to another. However, this practice may result in the loss of valuable information for improving future risk assessments. For example, understanding how well or how poorly a particular mitigation approach worked is extremely valuable in determining future mitigation methods. The post-mission analyses and dissemination of the results to all stakeholders is particularly important. Well-designed and well-executed monitoring programmes can contribute to the best available science and/or revisions of good practice for a particular type of survey, area of operation, and/or PSS. Unless they are provided with new insights in a timely way, regulators are likely to design regulations that are less than optimal and possibly even inappropriate.

A thorough review of a monitoring programme will:

- determine if monitoring results were sufficient to address and identify any residual risk to PSS;
- explore and analyse data to test for impacts;
- evaluate monitoring results to determine if mitigation measures as implemented were adequate to meet agreed objectives;
- include a report of an independent observer (when such an observer was present);
- evaluate operational procedures (e.g., communications, observation protocols) and identify successes/failures and describe reasons for both;
- provide advice for future mitigation and monitoring programme design. Such advice might be presented within a variety of fora, including publications (both peer-reviewed and non-peer-reviewed) and case study presentations to scientific meetings (e.g., Society for Marine Mammalogy), industry organisations (e.g., IPIECA, OGP JIP, IAGC), and meetings of environmental organisations (e.g., IUCN); and
- contribute relevant data from monitoring and mitigation to an appropriate centralised database. Regulatory agencies, rather than industry, may logically develop and maintain such broad databases (either at the national level or internationally through collaborations such as the International Offshore Petroleum Environmental Regulators, http://www.ioper.org/). However, specific results from post-survey reports should be included in broader databases that exist or may be developed. Access to such databases should be as open as possible, if not completely open then at least accessible to certified specialists.

C. Prompt analysis and availability of results

A common problem in characterizing and quantifying the risks to marine species from seismic and other environmental imaging noise is the lack of information or the inadequacy of best available science with which to estimate or predict effects (notably on the organisms' distribution and behaviour). Therefore, helping to fill data gaps needs to be considered a top priority for conservation biologists, resource managers (regulators), and industry alike. Even in areas where seismic surveys have been taking place for many years (e.g., the northern Gulf of Mexico, United States), there is a lack of information about effects and potential risks to wildlife. In designing mitigation plans, drafting EIAs, and preparing applications for permits, project proponents are expected to use the best available science, which typically means, first and foremost, the peer-reviewed literature. Where such literature is lacking or incomplete, there should be a strong incentive to collect relevant data, conduct appropriate analyses, and publish results in the peer-reviewed literature. In these instances, funds for analyses and publication should be included in the initial project budgeting and allocated at the outset of the planning process. Otherwise, there will be little incentive to support such work and, at best, its completion will be unduly delayed. Finally, the ultimate aim is to make sure that lessons are learned and applied to future mitigation and monitoring efforts in order to minimise the environmental impacts of surveys. Such lessons can be included in materials published on the mitigation and monitoring efforts, and publication may range from company reports to the peer-reviewed literature.

Steps to facilitate incorporation of results into future planning include:

1. Ensure that analyses are completed promptly and results published (at least in some cases in the open, peer-reviewed literature) to inform future risk assessments and mitigation and monitoring efforts:
    - Adequate funding for the analysis and publication of results needs to be included from the beginning of the process.
    - A chain of command for handling all phases of this process is a good idea, i.e., make provisions for personnel responsible for data collection, analyses and publication, from the outset. This is not to say that the same person(s) must be involved throughout the process, which can be lengthy, but instead that a chain of command to steward the data and the process should be established and maintained.
    - Use analysis methods identified in Practice 2 (see Annex for references).
    - Incorporate additional analyses required by regulators; these can often be incorporated into other ongoing analyses.
2. Identify and fill data gaps to support future activities and/or other exploration of the ecosystem; the use of best available science benefits all stakeholders as it lessens uncertainty, thus increasing predictability.

Practice 4: CASE STUDY

Woodside Energy Ltd: The effects on fish communities of Maxima 3D Marine Seismic Surveys at South Scott Reef lagoon, Western Australia[1]

Two series of Baited Remote Underwater Video Stations BRUVS (TM) surveys were conducted in an area of approximately 362 km^2 of Western Australia's South Scott Reef lagoon, in order to detect impacts of the 2007 seismic acquisition (Maxima 3D Marine Seismic Survey) conducted by Woodside Energy Ltd. The Maxima Pre-Post Surveys (MPSS) were conducted at 20 sites before and after Maxima 3D MSS. Due to the large extent of Maxima 3D MSS, all regions of South Scott Reef were likely to be affected, and it was not possible to find suitable control sites. All sites were located in the area covered by Maxima 3D MSS, and the sites were stratified unequally amongst three ecoregions that were determined to be relatively homogeneous in terms of fish habitats from previous benthic surveys. These ecoregions, dominated by live coral, were classified as: Deep-Water Foliaceous Coral, Deep-Water Coral Assemblage, and the less-extensive Deep-Water High Diversity. Each site was surveyed on four occasions, twice before and twice after Maxima 3D MSS.

A second series of surveys (Before-After, Control-Impact (BACI)) were undertaken to overcome the lack of controls in the MPSS. A small-scale seismic test was conducted immediately after the pre-impact phase. The limited extent of the seismic test allowed four impact sites directly under the test path to be compared to four distant sites that acted as controls. These impact and control sites were re-sampled immediately following the seismic test and provided a small-scale BACI study. Conducted before the overall seismic acquisition phase, the surveys took advantage of yet-to-be affected areas of the lagoon as control sites. At each site, four replicate BRUVS (TM) were deployed, with the aim of recovering at least three useful replicates in case of unsuccessful deployments caused by gear toppling on the uneven seabed terrain or through the influence of strong currents.

1 Australian Institute of Marine Science (AIMS). 2016, The effects on fish communities of Maxima 3D Marine Seismic Surveys at South Scott Reef lagoon, Western Australia: Baited Remote Underwater Video Stations (BRUVS (TM)) Surveys, http://data.aims.gov.au/metadataviewer/faces/view.xhtml?uuid=05966112-387a-4bdb-b27b-882ac1c2fe72

CONCLUSIONS

The processes and practices described here provide a structured framework for responsibly planning, implementing, and evaluating a seismic survey or other environmental imaging programme. From preparing, conducting, and evaluating surveys, to integrating lessons learned, this process aims to operationalize the elements illustrated in Figures 1 and 2, with specific lessons learned from case studies of operations around the world and in light of the many existing regulatory requirements for impact assessment, monitoring, and mitigation (Annex). The overall intent is to provide survey managers, industry operators, and regulators with a procedural guide that will help them conduct and manage seismic or other imaging surveys responsibly.

In order to retain the applicability of the proposed step-wise process across locations and programmes, and because there is great variability in the types of habitat where survey programmes occur, details are provided to allow for efficient planning without being overly prescriptive in terms of exact impact assessment criteria to apply or specific monitoring and mitigation measures to use. It is strongly recommended, however, that minimum standards for monitoring and mitigation (e.g., IFC Performance Standards) be maintained in following good environmental practice. More protective (or precautionary) approaches (e.g., the comprehensive application of the elements of the practices described here) should be implemented for critically endangered or endangered species where relatively high overall risk is identified in the pre-survey screening due to relevant contextual variables (e.g., presence of endangered or particularly sensitive species). Companies may be best served by identifying and adhering to common environmental practices that exceed the minimum standards required in a given jurisdiction, as this will increase both consistency and predictability in field operations and demonstrate that they are following good environmental practices. Finally, survey operators are encouraged to adhere to the principles of transparency and stakeholder engagement throughout this process.

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Annex

This Annex is an online tool for industry, regulators, and scientists to access information relevant to each of the four planning phases in the Effective Planning Strategy for Seismic Surveys and Environmental Imaging. The online database contains peer-reviewed literature, national and international government regulations and guidelines, technical reports, and reviews. Each database entry has several key pieces of information, including: country/ institution of origin, compliance (mandatory or advisory), region of applicability, applicability within the proposed framework, and whether or not the document contains relevant information for monitoring, mitigation, collection of baseline data, analysis methods, exposure criteria, cumulative impacts, or specified target species. Many of the guidelines shown in this Annex apply on a national scale, that is, within each country's EEZ or continental shelf margins. However, in cases such as the Arctic Council, the entire ocean basin is considered in the scale of the document. Other guidelines, such as in Western Australia, offer specific regional counsel on operational requirements for conducting seismic surveys.

The resources listed in this Annex are made available in an online database with corresponding keywords and links to the pdfs where available.

http://www.iucn.org/western-gray-whale-advisory-panel/panel/seismic-surveys-monitoring-and-mitigation

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