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Proceedings of the National Peer Review of a Risk-Based Framework for assessing Cumulative Impacts of Marine Development Projects (MDPs) on Marine Mammals and Turtles

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

The Fisheries and Oceans Canada (DFO) Fisheries Protection Program requested the development of a national approach and minimum standards for assessing the impacts of Marine Development Projects (MDP) on marine mammals and sea turtles. In particular, clear guidance was needed to identify the information required from proponents to assess the impacts, the criteria to determine probability and magnitude of impacts, the approaches to the management of uncertainty, and the ways to add impacts at the population and regional levels.

There is a need for industry, and a desire by Federal, Provincial and Territorial governments for an efficient regulatory review process for MDP. However, the lack of clear guidance and a national approach to impact assessment may lead to a perception of inter-regional and/or inter-project inconsistency, and unfairness in the reviews. This may result in extended dialogues and prolonged periods of review.

A scientific peer review was held in Ottawa in March 2015 to further develop a national risk-based framework. DFO and international experts in the field of acoustics, population dynamics, risk-assessment, cumulative impact assessment, and behavioural ecology attended. The scientific advice developed at this meeting could form the basis for a national standard for DFO when assessing impacts of MDP on marine mammals, and be used to develop guidelines to the industry for addressing marine mammal issues in their Environmental Impact Statements. This standard might also provide the basis for similar efforts for other marine biota.

SOMMAIRE

Le Programme de protection des pêches de Pêches et Océans Canada (MPO) a demandé qu'on élabore une approche nationale et des normes minimales pour évaluer les répercussions des projets de développement maritime (PDM) sur les mammifères marins et les tortues marines. Plus particulièrement, une orientation claire était nécessaire pour identifier l'information requise de la part des promoteurs afin d'évaluer les impacts, les critères qui déterminent la probabilité et la magnitude des impacts, les approches à la gestion de l'incertitude, et les manières d'intégrer les impacts à l'échelle des populations et au niveau régional.

Il existe un besoin de l'industrie, et un désir des gouvernements fédéral, provinciaux et territoriaux d'un processus règlementaire efficace de revue des PDM. Cependant, l'absence d'une orientation claire et d'une d'approche nationale d'évaluation des répercussions pourrait donner lieu à la perception d'un manque de cohérence entre les projets et les régions et de partialité des examens réalisés. Cela pourrait avoir pour effet un dialogue étendu et de longues périodes d'examen.

Un examen scientifique par des pairs a été tenu à Ottawa en mars 2015 afin de poursuivre le développement d'un cadre national de gestion du risque. Des experts internationaux et du MPO dans les domaines de l'acoustique, de la dynamique des populations, de l'évaluation de risque et des impacts cumulatifs, et de l'écologie comportementale ont assisté à la réunion. L'avis scientifique provenant de cette réunion pourrait devenir un standard national pour le MPO lors de l'évaluation des impacts de PDM sur les mammifères marins, et être utilisé pour développer des lignes directrices pour l'industrie afin d'adresser les enjeux liés aux mammifères marins lors de la production de leur énoncés des incidences environnementales. Ce standard pourrait aussi servir de base pour des efforts similaires pour d'autres biotes marins.

INTRODUCTION

An international workshop was held by Fisheries and Oceans Canada (DFO) in Quebec City in March 2014 to solicit the knowledge of scientific experts with experience in impact assessment approaches to guide the development of a draft national risk-based framework. Based on discussions from the 2014 workshop, a revised framework was prepared for formal peer-review in Ottawa in March 2015 by DFO and international experts in the field of acoustics, population dynamics, risk-assessment, cumulative impact assessment, and behavioural ecology.

The Chair, Dr. Garry Stenson, provided a brief overview of the purpose and specific objectives of the meeting, which were to review the draft framework for risk analysis and assessment, based on recommendations from the 2014 workshop, including the criteria to determine the probability and magnitude of impacts from various stressors on marine mammals and sea turtles, and to identify data gaps and proposed methods to address them (Appendix 1). It was stressed that the intention for this meeting was not to present a final product, but to review work in progress.

Participants introduced themselves (Appendix 2) and a brief presentation was given on the Canadian Science Advisory Secretariat (CSAS) peer-review process, and relevant policies and guidelines. Due to the late arrival of some key participants, the draft agenda was revised (Appendix 3) and approved.

Dr. Hilary Moors-Murphy (DFO – Science) was assigned as the lead rapporteur for the meeting.

The proceedings has 2 sections. The first section outlines the summary and discussions associated with the various presentations made by invited experts. The second section summarizes discussions on the proposed Cumulative Ecological Risk Assessment Framework (CERAF). Given that several of the comments received could not be incorporated without significantly altering the CERAF, the proceedings divides the comments that were addressed in the final research documents (Lesage et al. unpublished[1]; Lawson and Lesage unpublished[2]) from those that will be considered in the next iteration.

PRESENTATIONS ON TOPICS RELEVANT TO THE FRAMEWORK

LEGAL CONTEXT TO IMPACT ASSESSMENT IN CANADA

Presenter: Jack Lawson, DFO (Newfoundland & Labrador Region)

Summary: The current legislative tools for protecting marine mammals and sea turtles in Canada were reviewed. This included the *Fisheries Act* (FA), which currently protects habitat of commercial, recreational and Aboriginal (CRA) fisheries, including marine mammals, and provides indirect protection to some non-CRA species through protection of the habitat of their prey (if their prey is a fished species) or if they are prey of a CRA species. Under the FA, the Marine Mammal Regulations prohibit the killing, harm, or disturbance of a marine mammal (unless licenced by the Minister). The *Species at Risk Act* (SARA) prohibits the killing, harm and

[1] Lesage, V., Lawson, J.W., Gomez, C. (2016). Cumulative Ecological Risk Assessment Framework (CERAF) to quantify impacts from marine development projects on marine mammals and sea turtles. DFO Can. Sci. Advis. Sec. Unpublished manuscript (8817).

[2] Lawson, J.W., Lesage, V. (2016). Modelling ship strike risks for marine mammals and sea turtles. DFO Can. Sci. Advis. Sec. Unpublished manuscript (8818).

harassment of individuals of threatened and endangered species, and destruction of their critical habitat. The *Oceans Act* (OA) is an integrated oceans management tool that provides for the development of regulations, and establishment of objectives, criteria and guidelines to ensure the maintenance of marine environment quality (MEQ). This legislation was helpful in addressing cumulative effects, by allowing regulators to set some limits/thresholds (MEQ criteria) that should not to be exceeded for particular stressors, and by providing guidelines for implementing actions to ensure achievement of specific objectives related to maintenance of MEQ. The OA provides for the review of projects and in some regions, such as Nova Scotia and Newfoundland and Labrador, federal-provincial review boards have been established to carry out these reviews.

Fisheries and Oceans Canada (DFO) institutional objectives applicable in the context of a CERAF largely address issues related to the harm and harassment of individuals, population recovery, and availability of suitable habitat. The CERAF approach supports the accumulation of impacts from multiple stressors, rather than examining each in isolation, to account for synergies that may exist between stressors (e.g., the net impact of two stressors might be greater than the sum of each separately). Based on the following, the criteria against which to estimate impact likelihood and magnitude for Marine Development Projects (MDPs) or activities managed under the SARA, FA, and OA, would include the risk of:

1. *Causing permanent alteration to CRA species habitat;*
2. *Causing destruction of CRA species habitat, or of critical habitat of a species at risk;*
3. *Unauthorized killing of a species subject to the FA or SARA;*
4. *Harassing or disturbing a species subject to the FA or SARA; and*
5. *Compromising the recovery of a species subject to the SARA.*

Given these legal prohibitions, there was a need to determine the circumstances when effects (i.e., harm, harassment of individuals, compromised recovery), or when alteration or destruction of habitat were likely to occur.

Discussion: It was noted that some of the legal provisions from the OA pertaining to MEQ (Sections of the Act 32-d and 51-2) could be used to help set limits (thresholds) for specific stressors, and that this should be specified in the document presenting the CERAF (Lesage et al. 2016). It was also pointed out that while the *Canadian Environmental Assessment Act* (CEAA) has no specific provisions for impacts that are applicable in the context of this framework, the CERAF could be used as a tool in the context of assessments made under the CEAA.

Clarification was provided on the aim of the framework, which was to estimate effects both at the individual and population level, given the legal provisions (i.e., harm and harassment of individuals; compromising population recovery).

Acceptability of individual harm in the context of population level effects was assessed through the definition by managers of the level of risk acceptable under long-term recovery plan goals/objectives, in terms of total allowable harm (TAH) to a population.

A participant pointed out that the document presenting the CERAF (Lesage et al. 2016) should be modified to reflect the current interpretation of the FA regarding protection of marine mammal habitat. It was interpreted that the FA habitat provisions applied to all marine mammals, regardless of whether they were fished or not, or whether they supported CRA fishery or not.

THRESHOLD SETTING FOR PTS, TTS & DISTURBANCE – A NOAA PERSPECTIVE

Presenter: Amy Scholik-Schlomer, National Oceanic and Atmospheric Administration (NOAA) Fisheries (United States of America (USA))

Summary: NOAA's Office of Protected Resources (OPR) works to conserve, protect, and recover species under the *Marine Mammal Protection Act* (MMPA) and *Endangered Species Act* (ESA) by working with the Regional Offices, Science Centers, and various partners. One of the primary issues OPR deals with is assessing the effects of underwater sound on marine protected species (i.e., marine mammals, sea turtles, and protected fishes). NOAA's current marine mammal acoustic thresholds, which are typically applied to acute sources of sound associated with single activities and serve as a single tool within a much larger impact assessment, were briefly described (NOAA 2013). Since the inception of NOAA's current acoustic thresholds, there have been numerous scientific advances in the understanding of the impacts of noise on marine mammals, as well as the characteristics of sound sources that make them more injurious. Thus, NOAA was in the process of updating their acoustic thresholds via the development of a guidance document, which promotes consistency within the agency, as well as among proponents. NOAA specifically began by updating acoustic thresholds associated with permanent and temporary threshold shifts (PTS/TTS) based on the best available science. The PTS and TTS divided sources into two categories (impulsive/non-impulsive), provided dual metric exposure levels (peak pressure/cumulative sound exposure level (cSEL)), considered marine mammals in five functional hearing groups (cetaceans with low-, mid-, or high-frequency hearing, otariid pinnipeds, and phocid pinnipeds), and incorporated marine mammal auditory weighting functions. These updated thresholds were more complex than the current thresholds, which presented some challenges in terms of ensuring proponents, with varying levels of ability to model noise exposure, were able to correctly apply the new guidance. NOAA was working on developing simple, alternative approaches to assist proponents, as well as drafting a plan to ease the transition to the new guidance, since proponents were in varying stages of the application/permit/consultation process when the new guidance was finalized. Due to the complexities and high variability associated with how marine mammals behaviourally react to sound, thresholds associated with behavioural disturbance will be addressed in a future guidance document. As for the impacts of underwater sound on sea turtles, very little was known, and often marine mammal thresholds served as surrogate thresholds. However, a recent American National Standards Institute (ANSI) panel suggested that fishes provided a better analogy to sea turtles than marine mammals.

Discussion: Clarifications were requested regarding the management of Level A (serious injury and mortality) and Level B (sub-lethal) harassment by NOAA. The author responded that the National Marine Fisheries Service (NMFS) Stock Assessment Reports (SARs) set the Potential Biological Removal (PBR) levels and identifies accounts for the total annual human-caused mortalities and serious injuries inflicted on marine mammals, regardless of whether it is fishery-related or not. The sum of total serious injury and human-caused mortality inflicted by a project or any other activity in a given year has to be less than the estimated PBR. NMFS has classified PTS as an injury, but not as "serious injury," which was defined as more likely than not (i.e., greater than 50%) to result in death. Thus, these types of injuries were not accounted for in the SARs. Relating to acoustics, if an individual died as a result of an explosion or navy sonar (or other sound source), they were accounted for in the SARs. Sub-lethal effects (Level B) were taken into account in the MMPA permitting process. These included behavioural harassment, as well as PTS/TTS. Under the NOAA permitting process, incidental takes were approved if considered 'a small number' with no more than a 'negligible impact' and no 'immitigable adverse impact' on the availability of the species or stock for 'subsistence' uses.

A participant noted that classifying sonars as a ‘non-impulsive’ source may not be appropriate given that they have the characteristics of an impulsive source. The author pointed out that the classification used in the NOAA guidelines was based on Southall et al. (2007).

The group asked whether NOAA envisioned using non-threshold approaches to measuring the severity of behavioural responses. The author indicated that NOAA was open to ideas on that matter, although the retained approach needed to achieve the goal of quantifying behavioural impacts. In the absence of suggestions for new approaches to achieve this goal, the 120 decibel $(dB)_{rms}$ referenced to 1 μPa sound level threshold for non-impulsive sources is used to minimize behavioural impacts and stay within the Level B harassment category .

A threshold for behavioural effects (Level B harassment) from impulsive sound sources was developed specifically for harbour porpoises (160 dB_{rms}) because they appear to be more sensitive than other cetaceans that belong to the high-frequency functional hearing group (180 dB_{rms}). In the case of the low-frequency functional hearing group (i.e., mysticetes), thresholds for behavioural effects were extrapolated from studies of bottlenose dolphins. Some of the participants warned that bottlenose dolphins were fairly resilient and perhaps less sensitive than other species and thus, acoustic thresholds developed for dolphins may not apply to mysticetes. Using numbers developed for more sensitive species such as the harbour porpoise for species where hearing was not well-defined (such as for beaked whales) would be more precautionary. One solution would be to present the NOAA threshold table twice, once summarizing the best available science (where some cells would be blank due to knowledge gaps), and a second time including surrogate thresholds for functional hearing groups where data was limited or lacking.

The author also provided clarifications on the following points:

While acoustic modelling is used as part of the assessment process to calculate the number of Level A and B takes, there is no requirement from proponents to actually validate the accuracy of the acoustic model once a permit is granted.

The timeline for re-evaluating thresholds proposed in the NOAA guidelines will likely be every 3-5 years. However, the guidelines may be modified if deemed warranted following emergence of significant new information.

THRESHOLD SETTING FOR NOISE EXPOSURE – A HARBOUR PORPOISE PERSPECTIVE

Presenter: Andrew Wright, George Mason University (USA)

Summary: The impact of underwater noise on marine life calls for identification of exposure criteria to inform mitigation. Southall et al. (2007) proposed un-weighted sound exposure thresholds, but then suggested a weighting system (m-weighting) for determining received levels (RL) that filtered out some of the sound levels to which various marine mammal groups were exposed. This was problematic as the weighted RL never reached those of the un-weighted RL. Consideration of weighting of both the acoustic threshold and received sound was needed; this was acknowledged and done in the NOAA 2013 guidelines. However, the question of whether an audiogram-based weighting was more appropriate was posed.

Considering a range of field studies on harbour porpoises, there was experimental evidence to suggest that sound pressure thresholds for behavioural reactions or onset of negative phonotaxy were remarkably consistent across 11 studies. Threshold of reaction decreased with the increase in peak frequency of the signal, and paralleled the sloping audiogram, but with a 40–50 dB positive offset relative to the hearing threshold. A range of new TTS experiments suggested that harbour and finless porpoises were more sensitive to sound than expected. This information was extrapolated from studies on bottlenose dolphins that indicated TTS critically

depended on stimulus frequency, and that sound exposure levels (SELs) that induced TTS were reasonably consistent at about 100 dB above the hearing threshold for pure tones. The participants proposed that frequency weighting with a filter function approximating the inversed audiogram might be appropriate when assessing impact. TTS was frequency- and audiogram-dependent therefore the SEL and inverse audiogram/m-weighting seemed to be the appropriate metric to determine thresholds. Whether negative phonotaxis was a good proxy of behavioural impact remained as a knowledge gap.

Discussion: It was suggested that loudness curves would be more relevant than inverse audiograms to account for hearing capacity, but humans were the only species for which loudness curves (C-weighting) are appropriate. The author pointed out that they used loudness curves at first, however, the plotted TTS thresholds seemed to follow more closely A-weighting curves, and thus they found little support for using C-weighting.

ASSESSING CUMULATIVE NOISE EXPOSURE

Presenter: Christine Erbe, Centre for Marine Science & Technology, Curtin University (Australia)

Summary: The term 'cumulative sound exposure' typically referred to the total acoustic energy an animal received from one or multiple sources of noise over some period of time. Technically, the SEL was 10 times the logarithm of the received squared pressure (P) integrated over time (T). The SEL was equal to the root-mean-square pressure level (SPL_{rms}) plus 10 times the logarithm of the duration of exposure (T). The SEL was proportional to the total energy received. It was measured in dB relative to 1 μPascal^2 second (Erbe 2011).

$$SEL = 10log_{10}\left(\int_T P(t)^2\,dt\right)$$

$$SEL = SPL_{rms} + 10\log_{10}T \qquad [\text{dB re } 1\ \mu\text{Pa}^2\cdot\text{s}]$$

The SEL could be measured in the field, by recording the hydroacoustic pressure time series (P(t)) at the position of the animal over the duration (T), and using the above equation. In environmental impact assessments, prior to anthropogenic operations, the SEL was typically modelled using appropriate sound propagation models. cSELs were determined the same way, through measurement and/or modelling, using the above equation, integrating over long periods of time, during which noise from on-going or multiple sources was received.

A very simple example was that of a humpback dolphin (*Sousa chinensis*) swimming past an operating pile driver (Erbe 2012). Recordings of the pile driver at various ranges were used to determine a curve of SEL as a function of range (R) for every strike of the pile (Erbe 2009). The hypothetical dolphin swam past the pile driver in a straight line, with a closest point of approach at 200 m range, at a constant swimming speed of 5 m/s. Along this path, it was exposed to a series of hundreds of strikes. The SEL per strike increased as the dolphin neared the pile driver, and decreased afterwards. The cSEL, integrated over all strikes, monotonically increased over the entire path, asymptotically reaching a level of 202 dB re 1 μPa^2•s (Erbe 2012).

In a more complex example, cSEL was mapped over an entire coral reef during a seismic survey (Erbe and King 2009). The SEL received on the seafloor was computed for every shot of the 6-week survey, and integrated. The computational effort was reduced by two orders of magnitude by using a neural network to narrow down the acoustic propagation environment to 64 representative paths. The map of cSEL after 6 weeks of seismic surveying was overlain with habitat maps of the coral reef. The percentage of the reef area that was ensonified by cSEL above certain thresholds was calculated.

The cSEL could be determined in the field, for example, in the case of a tagged whale travelling through a noisy habitat. Acoustic recording tags on the animal could record the sound received over a period of time, from which cSEL could be calculated. Alternatively, the noise field could be measured by stationary hydrophones or modelled, and a periodically surfacing animal could be tracked visually while it moved through the noise field. The RL over time could be determined from the path of the animal through the measured and/or modelled noise field. This was done by JASCO Applied Sciences in the Sakhalin Energy grey whale monitoring project during a seismic survey in 2010, in which the sound level at the whale was estimated through modelling of the seismic source sound field adjusted by correlation with measured levels at fixed recorders.

Integrations of cSEL from shipping over very long periods of time (1 year) were done based on ship Automatic Identification System data in British Columbia waters (Erbe et al. 2012a). A map of cumulative hours of ship traffic by vessel class was translated into a map of cSEL. The modelled map of cSEL was 'validated' with measurements at 12 autonomous recorders. Given the differences in recording times and durations, absolute values could not be confirmed, but the ranking of sites in terms of received cSEL could be validated (Erbe et al. 2014). The cSEL map was thresholded by one of the water quality indicators suggested in Europe, where the annual average SPL_{rms} exceeded 100 dB re 1 µPa in the 1/3 octave bands centred at 63 and 125 Hertz (Hz) (Erbe et al. 2012a).

In a follow-up study, the received ship noise spectra were audiogram-filtered prior to integration over time, and the map of weighted cSEL was correlated with animal density maps for 10 species found in British Columbia waters (Erbe et al. 2014). The results were 10 maps indicating hotspots, where large numbers of animals are exposed to high levels of noise. As a next step, the weighted cSEL maps were correlated with the inverse of the density maps yielding opportunity or potential refuge sites, where large numbers of animals would be exposed to minimum levels of noise (Williams *et al.* 2015).

With the aid of improved processing algorithms and increasing computing power the modelling of cSEL has produced a variety of global maps of ship noise.

The temporal variability of cSEL was assessed by integrating over short periods of time and plotting the percentage of time that certain cSEL values were reached, or, after applying audiogram-weighting, the percentage of time that noise was audible to certain species. This was done in an assessment of ship noise from proposed industrial development in northern British Columbia (Erbe et al. 2012b).

A more complex scenario was that of entire populations of animals moving through a noise field and reacting to the noise as well as other environmental factors. Agent-based models or animal models try to estimate the path of individual animals through the environment, keeping track of the cSEL received by each animal. Behavioural patterns could be built into these models. Models could be run multiple times, and the cSEL would be presented as a statistical quantity over all receivers and runs. A number of such models exist, including, the Acoustic Integration Model (AIM), SAFESIMM, 3 MB/ESME, SAKAMATA, NEMO, InSPIRe, etc.

In any case, computing cSEL was simplified. The acoustic models and equations looked complicated, but they were well-established. The sound propagation models that were commonly used in environmental impact assessments were developed many decades ago and have been tried and tested in each ocean. Databases of physical and chemical oceanographic data were publicly available, from which the hydroacoustic sound propagation environment could be determined with reasonable accuracy in most of the world's oceans. The largest source of uncertainty in sound propagation modelling was typically the lack of knowledge of the seafloor geology, which determined the geoacoustic sound propagation environment. Uncertainty was assessed in the cSEL mapping exercise for ship traffic off British Columbia

(Erbe et al. 2012a). The errors in the source level, the hydroacoustic and geoacoustic environments, and the positions of receivers within each grid cell were estimated and their impact on the overall error in cSEL was determined by running the sound propagation model with the extremes of these input parameters.

Determining cSEL and its uncertainty is a well-documented technique. Scientists know how to accumulate exposures in a physical, acoustic way, but not in a biological way. Furthermore, the uncertainty of the physical model could be assessed, but not the biological model. A specific resolution or degree of confidence in the physical model could be achieved with little extra effort, in terms of time and money. Alternatively, a specific degree of confidence in the biological model would require enormous efforts and many years.

The big question related to the biological effects of cumulative sound exposure. How can the biological significance of cumulative exposures be determined? How do effects actually accumulate? Which properties are cumulative? What are the ‘damaging’ properties of sound (i.e., cSEL, intensity, peak pressure, pressure rise time, kurtosis, sensation level, particle velocity, etc)? Do these properties of sound combine at different thresholds to cause damage? Not all of these quantities are cumulative in a physical sense. Energy is additive and can be accumulated over time. The SEL of two strikes of a pile during pile driving was the sum of the SEL of each strike. SPL_{rms} is not additive and after two strikes, the SPL_{rms} was the same as after just the first strike. This was a result of the SPL_{rms} being the integrated squared pressure normalized by the duration. In the case of pulsed sounds, how should time be allotted for recovery between exposures?

Finally, how were the impacts of cumulative stressors assessed when dealing with acoustic or non-acoustic stressors? When were the effects of stressors synergistic? Were the effects of stressors additive or multiplicative?

Discussion: Clarification was requested as to how accurate the acoustic models were at predicting what was empirically measured. The author felt that the models were sufficiently accurate and that the uncertainty associated with the seafloor/benthic composition, which had a huge impact on the accuracy of the results, was properly estimated to give the results context.

The group asked about the spatial/temporal/frequency scales over which models were accurate in predicting exposure, and how uncertainty was incorporated in the predictions. The author indicated that accuracy at the various scales could be measured and validated with adequate data. Uncertainty associated with model parameters, such as seasonal variability in propagation properties, could be incorporated in acoustic models. However, the author reiterated that the highest uncertainty lay with the biology of the target species more than the acoustic modelling.

The group requested that the author provide recommendations for an operational way forward to add noise levels and sound exposure, including contributions from new MDPs. The author indicated that in Australia, proponents are requested to conduct a year of ambient noise monitoring at the location of the proposed MDP, and then conduct a statistical analysis based on these data to determine the baseline. Once an MDP is added, it is possible to calculate the proportion of time that noise levels exceed some pre-determined threshold.

This question led to a discussion on what should constitute an adequate baseline in terms of noise levels since, in some areas, current levels may already be too high and thus not the right reference point. A baseline close to the original communication space may be ideal, but the challenge was to determine this level while data existed several decades beyond this condition. Discussions around the constitution of an adequate temporal scale for cumulating noise determined that decisions must be both spatially-based and temporally-based. There was also a need to determine the resolution to be used for each scale, for example, in Europe a 5 km spatial scale and 1-day temporal scale was often used to calculate cSEL. It was also pointed out that the choice in acoustic model would be driven by the question of interest.

The group asked for clarification about how thresholds for cSEL were set for impulsive sources. However, it was pointed out that there were no guidelines for how to model and set such thresholds.

APPRAISING THE POPULATION CONSEQUENCES OF DISTURBANCE – HERE AND NOW

Presenter: David Lusseau, University of Aberdeen (Scotland)

Summary: In 2000, the United States Nuclear Regulatory Commission proposed the population consequences of acoustic disturbances (PCAD) framework to assess the way in which anthropogenic noise affected the conservation status of marine mammal populations. Recent research developments took this framework forward to estimate the probability that anthropogenic behavioural disturbances affected the demography of their populations. The Population Consequences of Disturbance (PCoD) framework (New et al. 2014) was used to estimate the mechanistic relationship between the activities of individuals and their condition concurrently with condition variability influences on the ability of individuals to make demographic contributions (by surviving or reproducing). For cetaceans, a number of studies pointed at decreased reproductive investment, more specifically decreased survival of calves to weaning age, for individuals that are exposed to repeated activity disruption caused by human activities at sea. Three recent PCoD developments, that addressed similar challenges in Canadian waters, were presented.

The most recent implementation of PCoD appraised risks associated with large developments in the home range of bottlenose dolphins in the North Sea, a conservation priority species. One major hurdle of PCoD implementation was the lack of data needed to inform the mechanistic relationships in PCoD. Thus, an interim approach was used, relying on expert opinion to inform the mechanistic relationships in PCoD where data was missing (Harwood et al. 2014). An individual-based simulation (New et al. 2013; Pirotta et al. 2016 review) was used, parameterized using data from the dolphin population and from human activities in the dolphin home range (Pirotta et al. 2013; 2014a; 2014b; 2015). The simulation predicted the cumulative exposure to different risks that the population would face under predicted development scenarios. This approach facilitated the assessment of the likely effects of the developments on the population's conservation status and appraised the uncertainty around this estimate. This interim PCoD approach represented a robust alternative to provide sound advice for development consenting decisions when a full PCoD implementation was not possible. However, a monitoring program should be set to collect the information needed to replace the expert opinion for future decisions. It therefore offered a first step for an adaptive management scheme.

A second example of the implementation of the PCoD framework was presented for minke whale tourism in Iceland. A compartmental energetic approach was used to estimate the likelihood that tourism exposure was influencing the reproductive success of female minke whales (Christiansen and Lusseau 2015). This approach first estimated whale activity disruption caused by vessel interactions (Christiansen et al. 2013a, 2013b). Spatially-explicit capture-recapture models were used to estimate the cumulative exposure of whales to vessel traffic over the foraging season (Christiansen et al. 2015). Finally, existing whaling data was used to estimate blubber mass minke whales acquired over a foraging season (Christiansen et al 2013c). From this compilation, females that were gaining more or less blubber than a typical whale over the season could be identified. These latter whales, whales in poorer condition, tended to have smaller foetuses too, possibly as a result of reduced reproductive investment during pregnancy (Christiansen et al 2014a). Finally, these estimates, along with their associated uncertainties, were brought together to appraise the likely effect of the whale watching industry on minke whale foetal growth over the foraging season (Christiansen and Lusseau 2015). A bioenergetics model (Christiansen et al. 2014b) was used to link activity disruptions to energy budget. This approach showed that current levels of exposure are unlikely to have population consequences.

Finally, new avenues to forecast PCoD from first principles were presented. This initiative aimed to develop prospective analytical tools for the rapid assessment (PATRA) of the PCoD. The notion of behavioural resilience (Nattrass and Lusseau 2016) was introduced as a metric to determine, *a priori*, the ability animals had to compensate for disturbances. The empirical work on PCoD concluded that this ability for compensation was the hinge on which cascading effects (demographic effects) might emerge from repeated activity disruption or displacement. A measure of resilience commonly implemented in community ecology, was used to qualify the resilience of animals to disturbance. This early work showed that more resilient individuals tended to recover faster from a disturbance and compensate for large environmental variability. This early fundamental work opened avenues to develop tools to provide a rapid categorization of populations able to cope with disturbance without their conservation status being affected.

Discussion: It was noted that NOAA often used expert elicitation, and this method of obtaining the best state of knowledge has withstood peer review, and the scrutiny of court cases. The key to this approach is in the number of experts consulted and ensuring they are from a variety of sources. A major difficulty is coming up with absolute values rather than relative scales.

The presentation demonstrated the “under-the-hood” calculations required to inform scientific advice on the change in population trajectory associated with the addition of new MDPs, and including uncertainty in these conclusions, which is the end product that is delivered to regulators.

MASKING: HOW DO WE ACCOUNT FOR THE INFLUENCE OF ANTHROPOGENIC SOUNDS ON MARINE ACOUSTIC ENVIRONMENTS (RE MARINE MAMMALS)?

Presenter: Christopher Clark, Cornell University (USA)

Summary: The ocean is alive with the sounds of life. Whales, dolphins, porpoises, seals, sea lions are well known for their complex diversity of sounds for communicating, mating, navigating, and foraging. There are no known deaf marine vertebrates, and fishes are known to produce an amazing array of sounds, especially males as part of reproduction. Emerging discoveries are beginning to reveal that marine invertebrates are listening and contributing to the chorus. The health of the ocean’s acoustic ecosystem depends on a normally quiet ocean, but ambient noise levels have increased dramatically over the last 40-60 years as a result of anthropogenic activities. The spatial and temporal scales over which human sound-generating activities influenced ocean acoustic ecosystems were presented. Examples of the resultant costs to whale populations were given. Global commercial shipping traffic accounts for 95-97% of world commerce. Offshore energy exploration and development, especially in the Northern Hemisphere, has risen steadily over the last 20 years. Sonar systems of all kinds: for defence, fishing, and resource prospecting have proliferated worldwide. These activities, in aggregate, have enormous influences on the marine acoustic ecosystem, especially in the low-frequency band (10-1,000 Hz), and there are few regions that remain acoustically pristine. Concern about noise impact has focused on acute effects (e.g., hearing damage, panic) that occur over relatively small areas under extremely rare circumstances. Impact assessments are based upon the estimated sound level to which an individual is exposed, but this dose-response paradigm fails to predict short-term responses under more typical situations because it fails to account for the behavioural or ecological context in which the exposure occurs. From a long-term perspective, especially given the chronic and near ubiquitous nature of elevated ocean noise levels, what is needed is a paradigm that accounts for the consequences of elevated noise levels on populations and ecosystems for extended periods of time. Thus, for example, studies indicated that right whales in the Stellwagen Bank Marine Sanctuary off Boston routinely lost more than 60% of their opportunities to communicate as a result of vessel traffic. The acoustic footprint from a typical seismic airgun survey raised background noise levels by 20-30 dB over areas as great as 100,000 km^2. The final point is this: it's not about whether or not human activities have impacted the marine acoustic environment or if tools are available to assess the spatial, temporal and spectral scales of human influences; it is about whether or not discussions over the scales of human impact will end and actions are taken to help restore the ecological health of the living ocean.

The purpose of the presentation was to discuss why loss of communication space (masking) is an issue, and to demonstrate how it can be measured. One of the points raised was that the only way to see impacts on individuals and populations is if they happen. However, once impacts have happened, it might be too late to act. One of the issues was the limited capacity of human observation, and the fact that not all impacts were observable. The present regulatory paradigm was not based on the best available scientific concepts and/or evidence.

There was a need to consider impacts at the appropriate scale and resolution (spatial, temporal, spectral). For low-frequency animals, the scale was the ocean basin. There was sufficient data to define the active bioacoustic space for some baleen whales (e.g., blue, fin, minke, humpback, right, and bowhead), and the characteristics of whale vocalizations. The question became, how much overlap is there in the active acoustic space of various species and various anthropogenic noise sources. For instance, there were thirty-five seismic operations on-going in the North Atlantic during summer in 2014.

One way forward was to focus on specific areas of concern for some species. Masking/communication space loss as a result of shipping activities was examined for right whales in the Stellwagen Bank area. Effects of seismic airgun noise on baleen whale vocalizations was also measured. One issue for marine mammal communication and acoustic space was the reverberation of noise at distance from seismic surveys due to acoustic smearing (i.e., the noise levels do not return to ambient between pulses - the noise becomes continuous).

Discussion: There were discussions about the scale of effects from masking and efficiency of mitigation. It was pointed out that mitigation measures associated with MDPs are largely inefficient in avoiding negative effects on communication space. In the case of baleen whales and other species communicating at low frequencies, masking effects can be ocean basin-wide and thus, animals would be unable to prevent the loss of their communication space by moving away.

The group discussed at length workable ways to include masking and loss of acoustic space into impact assessment of MDPs. The author cautioned about lumping masking with 'behavioural response', because the consequences are not observable; they result in loss of opportunity. As pointed out in the presentation, the data for defining the active bioacoustic space exist for several species, and it is relatively easy to model the footprint of different noise sources to identify where the problematic areas are by calculating overlap. A main challenge in assessing impacts is not defining the bioacoustic space, but determining how much of this space is actively used and thus has the potential to be lost.

In the Canadian legal context, an adequate acoustic environment is formally part of the definition of critical habitat and needs to be preserved. The challenge resides in defining the level of masking that impairs the functionality of the critical habitat and threshold beyond which there may be impacts on vital rates. There was a suggestion to use time series of marine mammal abundance and predictive models as a tool for assessing maximum sustainable yield and effects from MDPs, and more chronic noise sources such as shipping on population growth rates.

There was a consensus that masking/loss of communication space should be formally added to the CERAF as an effect distinct from behavioural responses, with an outline of the methods needed to calculate this effect. The group also agreed that ways to link changes in the acoustic environment to changes in vital rates should be explored further, although it was recognized that the current state of knowledge may be limiting at this time.

ACCOUNTING FOR BEHAVIOURAL CONTEXT IN THRESHOLD SETTING FOR ASSESSING DISTURBANCE

Presenter: Catalina Gomez, DFO (Newfoundland & Labrador Region)

Summary: At the March 2014 meeting, where an initial draft of the CERAF was reviewed, it was recommended that a literature review evaluating context-based behavioural responses of marine mammals exposed to various levels of anthropogenic sounds be conducted.

Building on the work of Southall et al. (2007), more than 300 literature sources including more than 40 species of marine mammals were reviewed to compile and summarize information on methods, species, sound sources, context of exposure and marine mammal behavioural responses. Species were classified in one of four groups depending on the hearing capacity, following the methods proposed by Southall et al. (2007) and NOAA (2013). Sound sources were categorized as being either impulsive or non-impulsive, and were described in terms of their pressure level (SPL), frequency (Hz), and duration/duty cycle. Received level (RL) and associated metrics at the location of the animal were also noted, along with the degree of mobility of the source, its depth and distance relative to the exposed animals, as well as the curiosity of exposed animals relative to the sound source. Some studies highlighted “sensation levels” or signal-to-noise ratio as important explanatory variables for the observed degree of animal reaction, but most reported RL as the main factor. One issue encountered was the high degree of variability between studies in how RL was measured and reported. Each study was also rated based on the level of detail provided in the study.

The degree of behavioural response appeared to be highly context-specific, and possibly influenced by the behavioural state prior to exposure, although there was high variability among studies in how behaviour was recorded. While six categories for context of exposure were defined in previous studies, these definitions were not used consistently in other studies.

Behavioural responses were assigned a severity score based on the scale proposed by Southall et al. (2007), where 0 meant “no response”, and 9 a “strong response”. However, several issues were identified with this categorization strategy. An alternative approach to that of Southall et al. (2007) was proposed to scale severity. The first modification was to consider observational severity indices and acoustic behaviour separately, so to rank them relatively and according to their biological significance. Alternate cut-off points from those proposed by Southall et al. (2007) for relative severity of behavioural impacts were also suggested: any reaction associated with a score of 3 or less was assumed to be of low biological significance; any response associated with a score of 6 or higher was assumed to be of high (6-7) or very high (8-10) biological significance; a score of 6 corresponded to a response that involved some avoidance behaviour or extended cessation of vocalizations.

It was recommended that clear guidance and standards be established for reporting acoustic data (metrics) and for designing monitoring programs to document potential effects of development projects, to facilitate comparisons among studies.

Discussion: The group generally agreed that this was a good and useful review of the literature, but was somewhat divided as to what to do with the data going forward. The authors pointed out that the review was not complete and there may be patterns that emerge in the future showing how animals change their behaviour in the presence of different noise sources. Some general statements about species and response to RL and context could be made.

The group was intrigued by the counterintuitive but consistent decrease in probability of a high severity response with the increase in RL among various types of non-impulsive sound sources. This triggered a general discussion about potential biases, and alternate approaches to data analysis. Key discussion points included the possibility that this reversed trend is associated with animals responding to lower RLs, or to sounds that mimic predators more strongly than other sounds. However, it may also result from increases in physiological responses, or from how the severity categories were defined. For example, animals may have the ability to increase response with increasing noise at lower level of severity (e.g., increasing swimming behaviour), but may not be able to increase response under more severe circumstances (e.g., if they avoid at 160 dB, but can't avoid again at 180 dB). Other key points included the potential benefit of looking at the data differently, for example weighting responses to account for functional hearing group and which component of the sound is actually received by the animal, examining each species separately, focusing on a specific sound source, accounting for differences between short but acute activities versus prolonged and constant activities, or accounting for differential sensitivity (e.g., critical time or habitat, etc.). The group generally agreed that splitting the data further will reduce sample size and may make it difficult to extract useful information, while not avoiding the naturally high variability expected in behavioural responses.

This discussion also raised the question of the adequacy of using behavioural response to RL in order to evaluate the severity of effects, given the observed variability and range of context-specific responses. There was a general consensus that RL may not be a good proxy for severity of response in all circumstances (e.g., the presence of vessels might be as, or more, important than RL of vessel noise; Pirotta et al. 2015). Alternate approaches to using RL could include the use of proximity as a metric. However, a majority of the group felt that RL cannot be rejected as a tool to assess exposure at this time, given the lack of an alternate, demonstrated valid, metric. In some cases, severity can only be assessed via behavioural response and rate of exposure. This would be the case, for instance, if animals strand following exposure, or if animals cannot afford to engage in anti-avoidance strategies.

There was consensus among the group that the Southall et al. (2007) approach needs to be revised to rank severity in a metric closer to biological significance and effects on vital rates. The author proposed an approach, but there might be other variants that could be examined. It was also pointed out that the duration and thus severity of a response may be related to species physiological needs (e.g., what might be "prolonged" for a harbour porpoise may be "brief" for a humpback whale), that severity scale is non-linear and thus should be interpreted with caution, and that a change in behaviour may be more easily observed in small odontocetes for instance, than in large cetaceans.

Clarification was requested as to whether the 'very-high severity' scores were excluded from the meta-analysis, and how that would impact the analysis. The author confirmed that this class was excluded from the analysis, but proposed to add it back and combine it with the "high severity" category. The group pointed out that outliers should be given more attention (e.g., beaked whales responding at lower sound exposure levels, possibly because of their antipredator response). The group also felt it is important to keep track of sample size in order to put a perspective on natural variability which may be large even when sample size is large (e.g., the dose-response study of killer whales by Williams et al. (2014)).

Suggestions to improve data representation included: plotting the actual data points for RL on log graphs to show range/fit of the data; flagging cases where mitigation was applied during activities and how it affected animal responses; and calculating a zone of influence (ZOI) from the reviewed studies to provide a better link to the methodology proposed in the CERAF.

The group requested that the box plot analysis be checked for sensitivity, and that what each dot represents, and how it weighs into the regression slope calculation be clarified in the resulting analyses. There was a concern that the slope of the regression curves was influenced by the statistical unit used and weight given to each dot. The author indicated that the dots were cases that may represent one or more individuals, and one or more studies.

To address some of the comments and suggestion made by the group, the authors proposed to rank studies according to data quality, modelling accuracy and reporting, and to evaluate impacts on the results. After discussing the analyses further with several participants, an alternate approach to account for the behavioural context in assessing disturbance was presented. The following section summarizes the comments received from the two iterations.

AN ALTERNATIVE APPROACH TO ACOUSTIC IMPACT ASSESSMENT NOT BASED ON RECEIVED-LEVEL OR BEHAVIOURAL RESPONSE

Presenter: Catalina Gomez, DFO (Newfoundland & Labrador Region)

Summary: Following the review of more than 300 studies with the aim of examining the effect of context of exposure to noise on behavioural response in marine mammals, it was concluded that the development of a generalized predictive model of acoustic impact, mediated via behavioural responses, based on RL may not be achievable given the variability in the data. Even if it was possible, such a model would require a level of contextual and quantified detail that would render them so complicated that they would be unfeasible from a management viewpoint.

In lieu of this, a new approach was proposed, based on the quantification of impacts as a proportion of habitat lost to a species. The approach should be associated with a decision tree/set of questions that determine particular situations where there are known conditions or contexts that may exacerbate or alleviate impacts beyond those calculated in simple area-impact model. Habitat loss could be estimated using acoustic metrics or physical metrics. For instance, the proportion of habitat lost could be defined in terms of time/area; as the largest of either (1) the area of avoidance or (2) the area over which acoustic impacts such as behavioural responses, masking or stress responses, might be experienced in the event that animals do not exhibit avoidance. The loss of acoustic space could be determined in various ways. A customized approach to impact assessment might be needed where (1) populations are deemed particularly sensitive or resilient, (2) acoustic exposure may be markedly changed by bathymetric features, (3) a large proportion of available habitat is likely to be ensonified, (4) few alternate habitats exist, or (5) animals may be exposed to additional threats or critical risk factors (e.g., reduced foraging success, increased bycatch or predation, mass stranding).

An outline of the proposed approach is provided in Appendix 4.

Discussion: The motivation for the discussion around habitat and communication space loss was that behavioural response is a polyphyletic metric that is difficult to separate into meaningful impacts as they are too species- and context-specific. While RL may be useful as a measure of severity of impacts, it would take years to properly eliminate studies in the literature that use improper measures or metrics for dB, and to standardize (when possible) severity scores. In contrast, habitat loss can be quantified in terms of area and duration of impact. The European noise management model has the merit of being relatively easy to apply and is a method that is readily available. The group agreed that this approach is worth pursuing, and that the draft approach should be included in the proceedings of the meeting (see Appendix 4).

However, the group also concluded that simply because the correlation between RL and response was low in the present study of a broad range of species, it did not mean that management should abandon the RL approach. Where good dose-response curves exist, this information could be incorporated when defining the size of the area where effects are likely to occur. It is mainly when dealing with ecosystem- or habitat-level analyses, or with a suite of species, that non-uniformity in response becomes overly problematic. There is research where dose-response curves were developed successfully to predict avoidance reaction (e.g., Williams et al. 2014).

Clarifications were provided on the European noise management model. In order to apply the habitat loss approach proposed, there is a need to estimate sound source levels, but not RL. In Europe, there is a series of thresholds for activities that are approximately similar, which are considered precautionary, and above which marine mammal displacement would be expected to occur. The European approach does not define the magnitude of the effect, but simply determines whether noise source levels exceed a defined threshold. It is a yes/no metric, and source level is used to define the size (and period) of the area impacted. In Europe, habitat loss is used as the key effect while masking is used as a proxy for more sub-lethal effects in general. The sound source threshold could be set to some level above ambient noise (e.g., 6 dB) as a way to set the size of a physical area that would cover the range over which sub-lethal effects would be expected to occur. This area is a measure of degradation of the habitat, and the area where impacts on vital rates and/or behavioural responses are expected to occur. The uncertainties (i.e., what level of habitat loss is acceptable) are similar or greater than the uncertainty around behavioural responses to RL exposure (i.e. how much change in behaviour is acceptable) although the habitat loss approach simplifies application for managers. In the Canadian context, the size of this area could be equivalent to the zone of influence (ZOI) from the CERAF. This habitat loss approach avoids many of the issues arising from measuring severity of behavioural response. In the Canadian context, the group indicated that estimating habitat loss is of particularly high relevance given there are provisions for preventing habitat loss both under the SARA and FA. With the habitat loss approach the question for advisors and managers then becomes what is the acceptable level of habitat loss, and in that respect, a decision will still need to be made. However, it is easier to make decisions based on a relatively simple metric (e.g., impact area, in km^2) than on behavioural response-based impacts, which are a lot more difficult to define.

The group agreed that the proposed simplification of the process for assessing behavioural effects of noise exposure is an improvement. There were however concerns that addressing masking simply through space/time measures is a somewhat static measure of something that has several components (periodicity, duration, space, frequency, and intensity), and is very dynamic. For example, masking occurs if there is overlap with an anthropogenic signal and an animal wanting to signal. In this case it is like taking a long-term average and ignoring the fact that all the sound peaks are driving the masking process.

The group also suggested that shipping might need to be treated differently in cumulative impact assessments, depending on current volume of traffic, consistency in noise level, and magnitude of sound energy added. Gaps in harbour porpoise distribution have been noted around major shipping lanes in Europe. In cases where the high volume of traffic already excluded marine mammals from an area, the examination of the cumulative impacts of additions to the existing traffic may not be warranted.

Finally, it was pointed out that in Europe, PTS and TTS are dealt with differently than displacement, and that physiological effects arising from marine mammals' persistence in using noisy habitats are not accounted for.

OVERVIEW OF THE CUMULATIVE ECOLOGICAL RISK ASSESSMENT FRAMEWORK (CERAF)

Presenter: Véronique Lesage, Jack Lawson, and Catalina Gomez, DFO (Quebec and Newfoundland & Labrador Region)

Summary: The proposed methodology for assessing impacts of MDPs in a cumulative, risk-based framework is presented in detail in Lesage et al. (2016). The approach is consistent with an ecological risk assessment framework originally designed for ocean management in Pacific Canada, since expanded to areas of the Arctic. Its process adhered to the International Organization for Standardization (ISO) 31000:2009 "Risk Management – Principles and Guidelines", which informed the development of an integrated ocean management (IOM) process for Canadian marine areas. Major steps include:

1. **Setting the Context:** The process of articulating an institution's objectives and defining its external and internal parameters to be taken into consideration when managing risks.
2. **Risk Identification:** The process of finding, recognizing, and recording risks.
3. **Risk Analysis:** The process of understanding the nature and level of risk, in terms of its impacts and likelihood of occurrence.
4. **Risk Evaluation:** The process of comparing the results of Risk Analysis with risk criteria to determine whether a risk and/or its magnitude is acceptable or tolerable.
5. **Risk Treatment:** The process of identifying and recommending risk control or Risk Treatment options

The approach is drawn from a number of initiatives, including the All Hazard Risk Assessment Methodology and Guidelines from the Government of Canada, the risk assessment methodology for key ecosystem components and properties developed by DFO, the impact assessment methodology developed for evaluating a seismic survey in California, the hierarchical ecological risk assessment for effects of fishing in Australia, the proposed extension of the PBR approach for including and cumulating non-lethal effects, factor-mediated risk assessment methodologies, and the EPIX ANALYTICS methodology for ranking risk and their severity.

The proposed CERAF involves a hierarchical assessment approach that extends from a comprehensive, but largely qualitative, analysis of risk through a more focused and semi-quantitative approach, and eventually that could evolve into an activity-focused and fully-quantitative 'model-based' approach. This progression is efficient because many potential risk factors could be screened out early in the process, so that the more intensive and quantitative analyses, with large data requirements, are limited to a subset of Ecosystem Components or Properties (CPs). It also enables more rapid identification of high-risk activities, which in turn can lead to requirements for immediate remedial action (i.e., Risk Treatment).

Specifically, the proposed CERAF is divided into five main modules (hereafter called "boxes"). Boxes A and B correspond to the procedures to assess and incorporate DFO's risk-tolerance into the assessment of a given MDP (Figure 1). Box A also serves to define management objectives, whereas Box B also serves to identify CPs and potential stressors associated with a MDP. Box C is the Risk Analysis and core of the risk assessment, where effects from the various stressors are assessed for their likelihood of occurrence, and individual or combined impacts. Box D corresponds to the Risk Evaluation step, and is the process of comparing the results of Risk Analysis with risk criteria, to determine whether the likelihood and magnitude of an effect, if it was to occur, is acceptable or tolerable. Box E corresponds to Risk Treatment, and provides for an evaluation of the efficacy of monitoring and mitigation measures proposed for the MDP in reducing the risk of impacts, including the uncertainty associated with efficacy of each measure.

CERAF STEPS ("BOXES")

Briefly, the Risk Analysis (Box C) uses information on population densities or size of key habitat, including uncertainty, along with spatial and temporal scopes for the various effects (using pre-defined thresholds) to calculate the zone of influence (ZOI) of each potential effect and to quantify exposure (N). The rate of occurrence of effect per exposure to the stressor (R), and severity relative to death or total destruction (S) would then be assessed. Modifiers can be applied to these quantities to account for features of stressor or CPs that might alter R or S. These steps integrate lethal and sub-lethal effects in a common currency that can be cumulated, and compared to those considered acceptable for single or multiple MDPs (Box D), using the scales for Impact Magnitude (I) developed independently from the MDP evaluation (Box A).

Risk tolerance would be determined by factors both extrinsic (Box A) and intrinsic (Box B) to the MDP being evaluated. Extrinsic factors unrelated to a MDP (Box A) such as climate change variability or current CPs exposure to environmental stressors, might alter the probability for impacts of a MDP, and are summarized as a Vulnerability Index (VI). Vulnerability of CPs would be assessed independently from MDPs, and factored into MDP assessments at the Risk Evaluation step (Box D), by adjusting the scale for ranking impact magnitude (e.g., toward lower acceptable allowable harm for CPs with higher vulnerability). The scale for impact magnitude rating may be adjusted further by DFO authorities, depending on the acceptable level of harm to a CPs they are willing to accept both globally, and from individual MDPs.

Factors related to a MDP that might alter the magnitude of impacts, either by changing effect severity directly, or by changing the rate of effect per exposure (R), are assessed in Box B. The Sensitivity Index (Rm) summarizes the amount of change in severity of effects (S) expected as a result of specific characteristics of a MDP or CPs that may augment exposure (e.g., the degree of overlap with critical life processes or key habitat, duty cycle of a sound source, CPs' behaviour, functional hearing, etc.). Stressor-specific sensitivity, Rs, is expressed as a modifier applied to the Severity Score (S) for a given effect, and is a metric that assesses, on a common scale (from 0 to 1), the severity of sub-lethal effects (i.e., < 1) and lethal effects (i.e., $= 1$, removal). Another metric, called modifier R, accounts for MDP characteristics that might alter the rate of effect per exposure, e.g., effects of vessel speed on the probability of lethal outcome of collision per encounter. These factors cumulate into the output of Box C, which represents the number of individuals whose vital rates are likely to be affected by given stressors. Importantly, all these parameters include measures of uncertainty.

Box C presents two approaches to Risk Analysis that require a common data foundation, but also approach-specific sets of parameters: 1) a semi-quantitative "Matrix-Based Methodology" that was adapted from existing approaches but expanded to explicitly include vulnerability and sensitivity indices, and to assess cumulate risks more quantitatively; and 2) a "Population Viability, Energetic and Behavioural/Movement Modelling Methodology". This dual approach was proposed to account for variability in data richness or modelling capacity, as well as for species-specific risk-tolerance. For instance, a population trajectory modelling approach may become a mandatory step in an assessment when Species At Risk are potentially impacted, or for populations for which impact magnitude are deemed high or medium by the matrix-based methodology.

In the Risk Evaluation step (Box D), Magnitude of Impact (I) obtained from the Risk Analysis is combined with a Likelihood function to assess Risk. Likelihood has two components: (1) the likelihood that a stressor (L_s) (with characteristics likely to cause an effect) will result from activities of the proposed MDP (e.g., chance of noise in excess of threshold for causing PTS, or of an oil spill >700 tonnes), and (2) the likelihood of the stressor causing an effect if it does occur (L_e) (e.g., chance for an oil spill to cause death of a killer whale or sea otter; chance of noise in excess of 120 dB re 1 uPa_{rms} of causing disturbance). These likelihood scores (L_e and L_s) can be combined mathematically with the impact score I for each stressor/effect to assess individual risks. These risk scores are then summed to obtain a cumulative risk for each stressor, activity or CPs. A logarithmic scale would appropriately capture the idea of magnitude change between L and I categories that generally characterize risk severity scales.

The CERAF process could be completed while either excluding or including monitoring and/or mitigation measures to assess their value in reducing risk (Box E, Risk Treatment). Efficiency of mitigation measures could be accounted for in various ways in the framework depending on their nature. Measures that involved surveillance of exclusion zones could be factored in through an index of efficiency (E) of the mitigation measure. Mitigation efficiency rating may also take into account the quality of the mitigation protocol, and qualification and experience of those implementing the mitigation measures. Given the evident difference among industrial proponents in the experience and success in implementing monitoring and mitigation protocols, the framework proposes to adjust the risk reduction capability of these protocols based on proponent past history as well. Results of on-going monitoring could provide feedback into follow-up iterations of the framework so that changes in stressor characteristics, CP status, and measured impacts of stressors can be assessed.

The CERAF was summarized in general terms by the Chair of the meeting (Garry Stenson) on the last morning of the meeting, and is provided schematically, below (Figure 2).

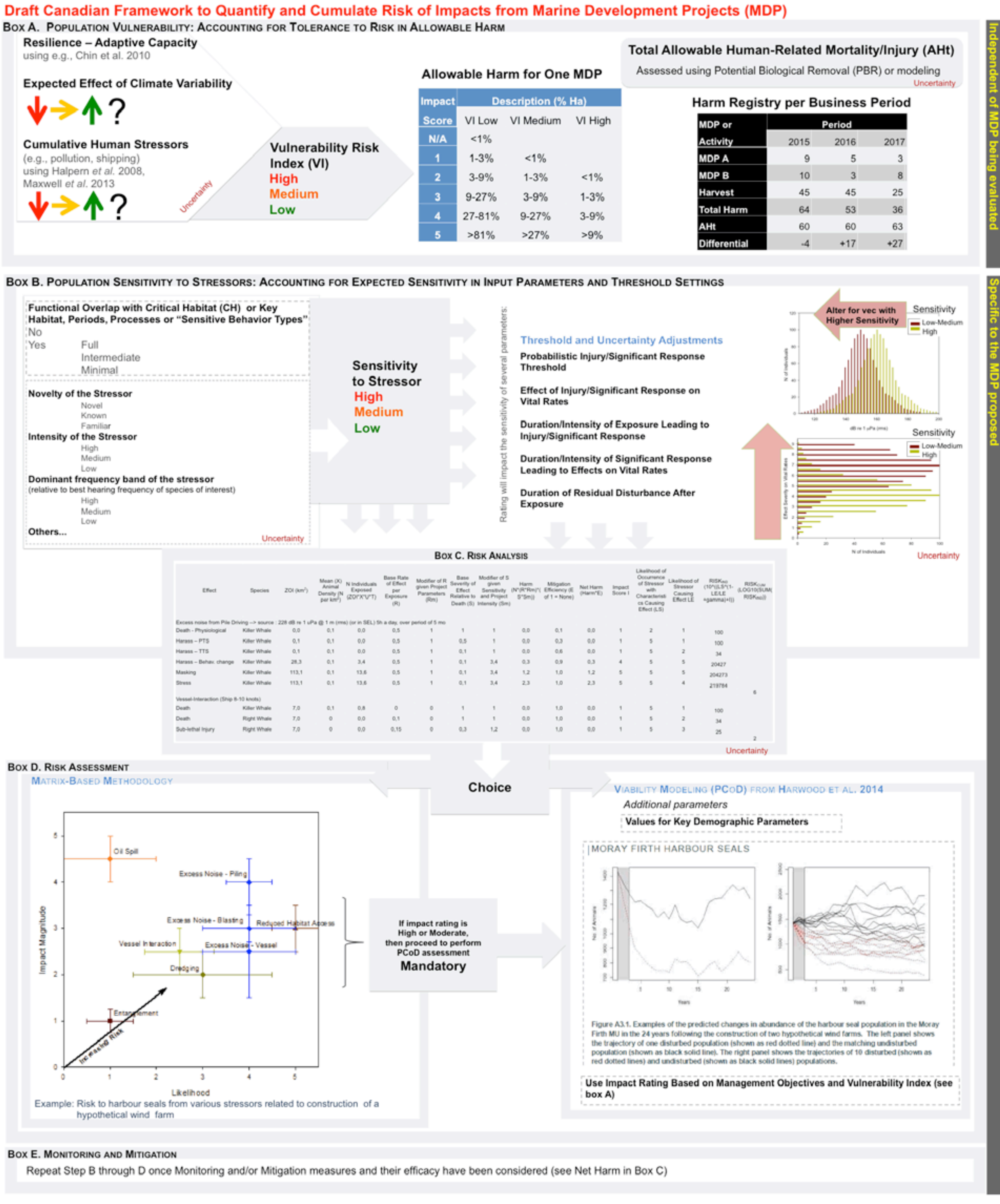

Figure 1. Visual representation of DFO's proposed Cumulative Ecological Risk Assessment Framework (CERAF) process, apportioned into five main process steps (termed "boxes").

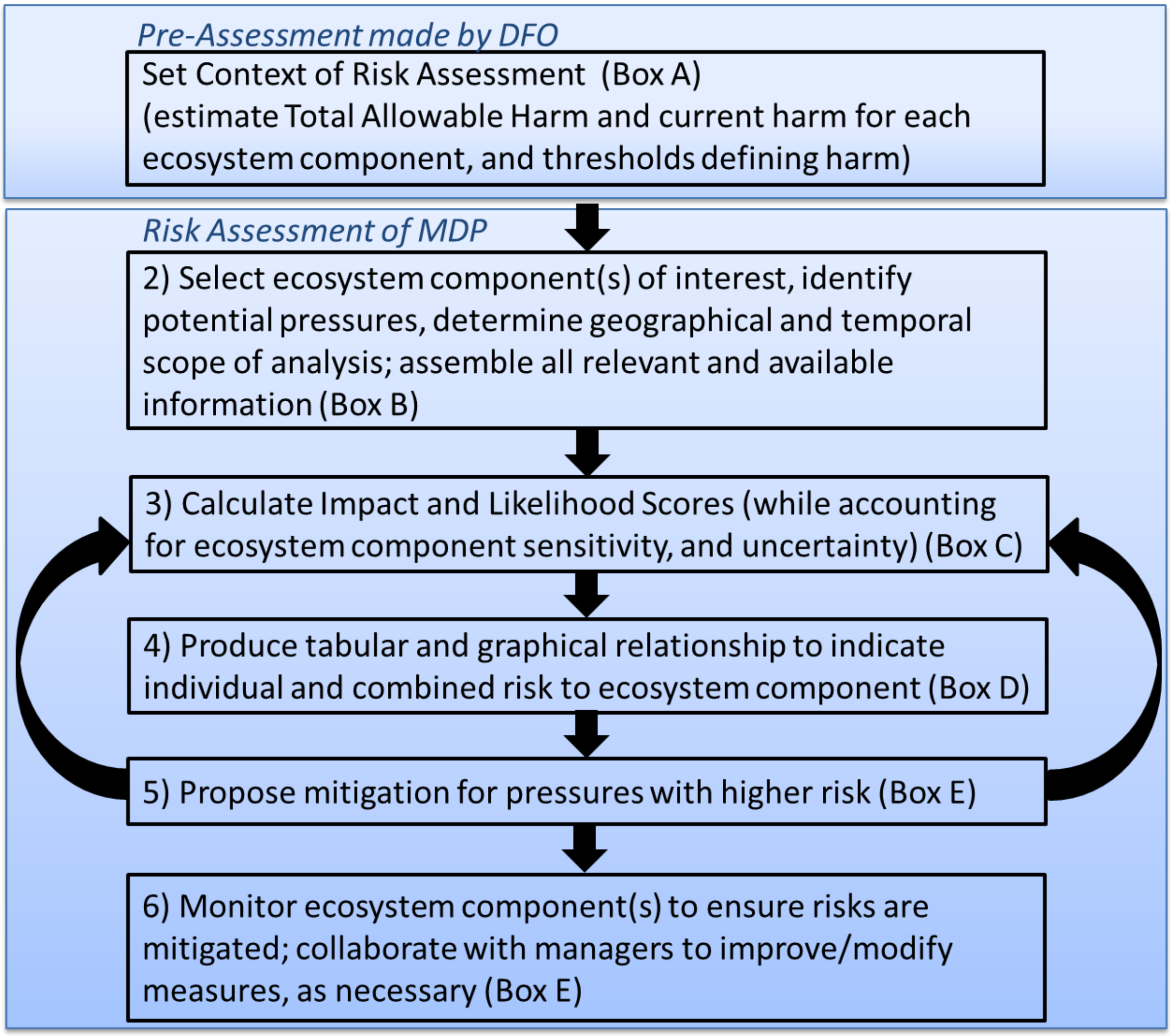

Figure 2. Overview of the stages in the CERAF to quantify the potential impacts associated with Marine Development Projects (MDPs).

GENERAL COMMENTS ON THE PROPOSED APPROACH

The group conveyed that the proposed CERAF sets the basis for a thorough review of MDPs, and incorporates ways of addressing many of the issues that are frequently not accounted for in MDP evaluation, including species vulnerability, species-specific sensitivity to specific stressors, loss of acoustic space or habitat access, uncertainty, and in particular, combined effects. While the group agreed that the proposed approach is fundamentally a major step forward and its development is worth pursuing, there was a general concern that the proposed approach currently may be too complex to enable its operationalization, and therefore needs to be simplified. The authors recognized that incorporating all of the factors that the scientific community and management feel are important to consider when assessing MDP impacts, particularly in the Canadian legal context where population level effects need to be determined, is difficult to reconcile with a simplistic approach. Adding clarity as to the sections that would be accomplished by DFO Science or with the support of DFO Science, and the background information made available to the proponents and internal users prior to creation of their project proposals, would contribute to alleviating this perception. For instance, there is an intent to develop a computer-based interface where up-to-date data on each of the species' conservation status, abundance, biology or habitat, scores for specific criteria (e.g., vulnerability index and several of the factors contributing to estimating stressor-specific sensitivity) is available, as well as tools for calculating net harm or sensitivity, to aid proponents and analysts in applying the framework. While the group acknowledged that these would facilitate operationalization, there was a consensus that further simplification of the CERAF is still needed. For instance, there was a suggestion to review the factor and risk scales (0-5, 0-3, 0-1) used in the framework to change them all to a common range of values (e.g., 0-1), hence reducing complexity.

The group also indicated that while the legal landscape is complex in Canada, the point of the framework is to provide a tool for decision makers, and to provide guidance to proponents about what information is required to complete an assessment, how to calculate impacts, and to the extent possible, provide managers and proponents with the impact thresholds that should not be exceeded. In the UK for instance, the first stage in an MDP process is creation of a strategic Environmental Assessment (EA) by the regulators within which limit thresholds are defined. An EA is then completed by the proponent, who must demonstrate that they will not exceed the thresholds. In the current CERAF, the strategic EA would be equivalent to Box A, and the EA created by the proponent would be equivalent to Boxes B-E (Figure 1). The group conveyed that project size and level of risk are completely unrelated and thus that the same level of managerial scrutiny and methodological rigour should be applied regardless of project size.

The group came to the conclusion that the CERAF (which is consistent with the ISO 31000: 2009 “Risk Management – Principles and Guidelines”) follows an acceptable logic. An earlier suggestion to incorporate mitigation directly into the risk analysis (Box C), rather than considering it separately once a first evaluation of risk was made,, but was not accepted by the group following discussion. Some participants at the scientific peer review emphasized that it is a standard requirement in DFO to transparently produce assessments both with and without mitigation measures, and provide both resulting impact estimates. The group concluded that the initial risk assessment should be concerned with identifying and understanding the MDP-related risks without mitigation, and to then understand the added benefit of the mitigation measures.

The group noted that the definition of the Total Allowable Harm (TAH), and the reliance on the number of animals exposed in the Risk Analysis step, both assume that minimal information exists on abundance, which is not the case for many Canadian marine mammal stocks. The CERAF approach also implies that each stressor follows a pathway that ends in changes in local abundance. These features should be highlighted in the document, along with a thorough discussion of the minimum amount of information necessary to make a decision with the CERAF. The group concluded that cases where there is simply no information for some marine species will always be problematic, regardless of the framework used. It was pointed out that in cases where minimal abundance estimates don’t exist, it might still be possible to estimate a TAH but given the uncertainty, the TAH estimate may be a minimum. Acquiring information on seasonal marine mammal abundances to lower uncertainty and increase TAH might be an incentive to acquire new data.

In cases where sufficient information are not available, it might be possible to widen the application of the CERAF framework by relaxing the requirements in the pre-assessment step through replacing the term “Total Allowable removals” with “Total Allowable harm limits”, and “abundance” with “indicator” so as to be inclusive of the kind of data that are available for the MDP site and relevant species. Biological indicators could be measures such as (1) pregnancy rate or blubber thickness, which are data that is currently available for harvested animals, (2) pup counts (e.g., seals) or calf survival (e.g., southern resident killer whales), or (3) areas of available habitat, etc. Such an approach would allow easier linking of changes in some features of the habitat with indicators such as body condition, but not necessarily population size. This could be integrated in the Risk Analysis and Risk Evaluation steps (Boxes C and D) by replacing the Impact Score (Y-axis) (see Figure 1, Box D) by any suitable metric. But doing so would necessitate a change in the way the CERAF is used to derive impact estimates. It would be useful to explore this alternative methodology using a data-rich species for which good information exist on abundance and other biological indicators to test for robustness and potential issues, and to prioritize knowledge gaps. Populations such as St. Lawrence Estuary beluga (*Delphinapterus leucas*), North Atlantic right whales (*Eubalaena glacialis*), southern resident killer whales (*Orcinus orca)*, or Northwest Atlantic harp seals (*Pagophilus groenlandicus*) would be good candidates. If one could develop ways of including the proposed dichotomous approach to data richness this may help streamline the process of applying the CERAF.

The group recognized the benefit of using a PCoD approach, and appeared more comfortable with this approach than the proposed CERAF's factor-mediated framework for assessing impacts on individuals and populations. However, the group recognized that application of PCoD for regular assessment may not be realistic as it takes a long time to populate the required data input tables and run the model for each species of interest (e.g., four case studies were run by Lusseau and collaborators over a five year period). Therefore, even in cases where sufficient population data exist, an alternative to PCoD is required. The group also recognized that data deficiency is a limiting factor for applying PCoD as a mandatory step even when risks are considered high or moderate, and that this should also be clearly indicated in the document summarizing the CERAF (Lesage et al. 2016).

Clarifications were requested on possible delays in performing and reviewing EAs as a result of using the new CERAF, and on the DFO internal process for evaluating EAs submitted by proponents. The authors did not anticipate increased assessment times to a point where the process becomes unworkable. EAs submitted by proponents are consistently evaluated by DFO, but the process varies depending on anticipated risks. Usually those with anticipated higher risks are submitted to DFO Science for more in-depth scrutiny using a peer-review process overseen by the CSAS, although this is not always the case. It was suggested the authors clearly indicate in the framework document that the evaluation provided by the proponent is to be validated and reviewed by DFO authorities.

There was a consensus that assessing acoustic space (and loss thereof) needs to be considered in the CERAF, and that this represents a huge step forward compared to what is currently being done elsewhere. The legal context in Canada, where maintaining a suitable acoustic environment is often part of the features identified as essential for maintaining the functionality of critical habitat for marine mammals, relies on that kind of evaluation. The group concluded that assessing loss of communication space and degree of masking can be done with the currently available methodologies, but that the next and most challenging step will be to link loss of acoustic space or degree of masking with effects on biological functions and vital rates. At this point, DFO may have to fall back on assumptions or expert elicitation until better data can be collected. It will also be important to place these effects within a population context and in metrics that are practicable for most managers.

The group discussed the necessity for clear guidelines regarding the appropriate acoustic metrics and how they should be measured. It was also pointed out that the CERAF methodology should allow for determining the contribution of each MDP to the loss of acoustic space. The group also warned against choosing inappropriate reference points as many locales in Canada disturbed by anthropogenic activities may already exceed thresholds where significant effects are likely to occur. The time period over which effects are likely to become significant also needs to be addressed.

In reaction to a statement that incorporating transient noise sources into cumulative mapping of stressor intensity is challenging, it was pointed out that there are ways to do this and although challenging, representation of impacts should be integrated over time (i.e., avoid static or uniform activity or impact maps).

With regard to cumulative impacts, the group suggested that the current implementation of the CERAF addresses *additive* impacts, but not *cumulative* or *synergistic* impacts. For example, the CERAF should examine impacts of MDPs occurring simultaneously or in succession, or additional impacts on animals moving from one project area to another where new threats may materialise. How the CERAF accounts for cross-project impacts could be presented more clearly both at the Box A step when calculating current harm relative to TAH, and at the risk analysis and impact assessment steps (Box C and D) when calculating number of individuals potentially harmed. The group recognized, however, that accommodating the combined effects of multiple MDPs is highly challenging, and that DFO should consider a means to facilitate access to the data on effects from other MDPs in the same area or impacting the same species or habitat. A mapping tool could help visualize temporal and spatial overlap of MDP activities and species under consideration.

The authors agreed that, during risk analysis calculations, more clarity could be achieved by substituting the number of individuals potentially harmed for “net harm” as the number of individuals potentially harmed is independent of the likelihood of occurrence. This modification to the CERAF would allow managers to decide on what level of likelihood they consider is equivalent to “likely to arise” versus “unlikely to arise”. They would then be in a position to evaluate stressors that would have a big effect on the population, but that are unlikely to arise, separately from those that may have a lesser impact on the population, but are more likely to occur. These evaluations could then be compared back to the estimates of TAH. For instance, a manager could decide that anything with a likelihood rank of 3 or above is likely to arise, then tally the harm (removals) for all stressor effects with a value of 3 or above, and compare it to TAH or cumulate those as probable harm associated with a MDP.

In calculating individual and cumulative risks, the group recommended that test cases be presented as a means to help proponents and managers determine whether such calculations are appropriate to scale risks in a way that reflects potential impact magnitude.

The group concluded that while the current CERAF is relatively clear in outlining the mechanics for calculating harm to populations, this is not the case for harm to habitat, and that more consideration should be given to habitat-related criteria both for evaluating vulnerability and stressor-specific sensitivity, and overall risk.

The group recognized that although relevant to MDP assessment, the framework does not address trans-boundary issues (e.g., inter-provincial or international), which would obviously add complexity to the impact assessment. It was suggested that this should be addressed at least qualitatively as part of the risk analysis.

There was general agreement among group members that animal stress is an important aspect to consider. However, the group recognized that data are currently insufficient to determine the magnitude and healthy limit for marine mammal and sea turtle stress, and thus to fully consider this aspect in the current CERAF.

The group recommended that the CERAF clearly highlight where acceptable baseline data (e.g., ambient noise, habitat use, etc.) is required, what characteristics of the baseline data are used to define “acceptable” (for instance, spatial and temporal scale), and indicate that the regulatory, pre-assessment framework (Box A) needs to be established in order for the CERAF to be fully implemented.

The group suggested the authors replace the wording “best available science” with “best available information”. The authors noted that data quality is factored into each of the criteria involved in assessing sensitivity and vulnerability. However, the group felt that it is crucial that the CERAF address uncertainty in a more transparent manner; the document be revised to more thoroughly present how uncertainty is addressed at each step of the CERAF.

SETTING CONTEXT – ESTIMATING TOTAL ALLOWABLE HARM WHILE ACCOUNTING FOR CP VULNERABILITY (BOX A)

The authors clarified the definition of TAH: it is the number of individuals that can be harmed without jeopardizing the population.

The group recommended that DFO regulatory sectors need to develop population-specific management objectives and assess their tolerance to risk, as a pre-requisite for using products such as the proposed CERAF. The Science sector can help in this process by providing a review of the best available information for defining limits/thresholds corresponding to each of the management objectives. Incorporating CP’s (i.e., species or habitat features) vulnerability into TAH may take some time to implement given the need to evaluate each CP for a number of factors. DFO Science would be responsible to provide a vulnerability index (VI) and data for each of its components. The question of setting limits/thresholds for determining when management objectives have been compromised, or when effects are likely to occur, can be addressed in simple or more complex ways. The group recommended DFO opt for simple approaches to help users understand and apply the proposed methodologies.

Clarifications were provided on ways to deal with new incoming projects that might increase TAH to unacceptable levels. For instance, in the case where DFO anticipates the proposal of several MDPs in a specific area, they could decide to accept a lower maximum harm per MDP to allow multiple MDPs to go ahead. Although challenging to implement, the development of a business cycle for MDP submission/evaluation could ease this process. In the interim, an on-line registry of MDPs and associated harm could help keep track of total harm and insure that management objectives are not compromised.

Assessing vulnerability of CPs was recognized as an advantage of the CERAF. However, there was much discussion on the intent of the Vulnerability Index (VI). Some confusion arose from the misunderstanding that this step is not to be completed by the proponent, but by DFO Science Further explanation was needed for how VI was accounted for when setting allowable harm for a given MDP evaluation (Table 6). A suggestion that achieved group consensus, and which would also reduce the complexity of the CERAF for analysts and proponents, was to account for CP vulnerability directly when DFO sets TAH rather than modulating the allowable harm per project using the VI. It was also proposed to review the VI whenever DFO conducts an assessment or estimates TAH.

The group recognized that the CERAF, including its use in defining TAH and VI, is currently better able to deal with CPs that are species than with CPs that are habitat. The group concluded that habitat CPs are very important to address, and that criteria to assess TAH, vulnerability and stressor-specific sensitivity should be reviewed carefully to ensure the best metrics for assessing acceptable harm to habitat (i.e., not affecting the habitat’s normal functions). There were suggestions to examine recent DFO CSAS publications addressing vulnerability and resilience of fish habitat to identify potential ways to improve the currently proposed CERAF approach. However, it was recognized that defining habitat attributes may yet prove challenging in many cases, for instance, there were considerable efforts made in the United States by NOAA to assess habitat resilience (as an aspect defining CP vulnerability), but that this was found to be highly challenging and generally unsuccessful.

The CERAF proposes different ways of setting TAH, including population modelling and Potential Biological Removal (PBR) or similar. It was pointed out by several members of the group that there was a risk of over-estimating vulnerability if using the PBR approach (as opposed to population modelling) for calculating TAH. This is because the PBR's recovery factor (Fr) may already account for vulnerability and the reduced capacity of some species/populations to recover compared to other groups. One possible way to circumvent this caveat when the use of PBR is necessary is to calculate PBR without Fr, or alternatively use PBR with Fr but without calculating the VI. However, this would only work if vulnerability is the only criteria for Fr, which may not be the case.

Inter-birth interval has been used in the CERAF as a metric of resilience. However, it was also noted that for some species, data are available to provide an actual resilience measure for life history features, rather than relying on a rank defined only by inter-birth interval. It was also pointed out that inter-birth interval might not be the best metric for resilience to choose from life-history characteristics, and that population structure, and associated uncertainty could also be used to estimate resilience.

THRESHOLD SETTING FOR DEFINING HARM (BOX A)

The group agreed with the authors that deriving thresholds for defining harm remain challenging for several stressor-effects.

In the context of the two presentations on the alternative approach to assessing the behavioural effects of noise, most of the group concurred that estimating impact magnitude based on RL is too simplistic. Alternative means of assessing behavioural effects from noise were proposed during this discussion (see summary of presentation by Gomez et al., this document).

In the specific case of entanglement, it was pointed out that while many factors interact to cause entanglement thus reducing our capacity to predict project-specific risks, there is adequate knowledge available for some species to estimate entanglement risk and to predict the efficiency of some mitigation measures (e.g., acoustic pingers for reducing harbour porpoise bycatch).

ASSESSING CP SENSITIVITY (BOX B) AND ANALYZING RISK (BOX C)

There was consensus that the proposed methodology for calculating stressor-specific sensitivity is very complete in taking into account the many facets of CP-related sensitivity that are to be considered when evaluating MDP impacts, and that it represents a major step forward.

However, the group felt that the proposed methodology is limited in two ways: it relies on many parameters which implies a level of precision that may not exist, and the CERAF comes across as overly complex. The authors described how expert elicitation could be employed as a means to acquire information when data are lacking, and will be used for those cases in the CERAF. The group agreed that this scientific method is currently used in court cases in the US, and is recognized as a valid method when specific data do not exist. In the DFO framework, however, the number of places where expert-based values will be needed might be problematic. There was a strong suggestion from the group to try simplifying the approach to make it better able to be used as a management tool. It was proposed that the authors proceed with identifying key parameters for each of the stressors and effects (e.g., probability of colliding with a ship in the case of North Atlantic right whales), and consider how they might collapse several of the parameters into a reduced set. For example, the number of animals exposed using thresholds (e.g., sound dBs) could be calculated, factoring in their sensitivity as a modifier to exposure (by changing radius or dB), and merging severity, its modifier, and the two likelihoods into a probability distribution of harm. Unfortunately, the way in which distribution is obtained is currently unknown.

Along the same lines, it was pointed out that in the case of North Atlantic right whales and the collision risk, the CERAF would estimate risk based on only two metrics (i.e., the distribution of whales and distribution of the traffic) to identify areas of overlap. The information related to surface behaviour and other factors likely to affect collision risk were deliberately taken out of the estimation process simply because data were unavailable to predict these behaviours and where they would take place. In this particular case, the mitigation measures implemented were proven to be very efficient in reducing the risk of ship strike for right whales.

It was suggested that in some cases, a reverse-engineering of the PCoD approach where, for example, the number of days of behavioural disruption that leads to the loss of one animal is calculated, or the percentage of the population affected or duration of exposure to yield a given severity of response is changed, might be a method to fill in missing data for parameters and obtain the modifier values. However, it was recognized that this type of modelling also relied, to some extent, on expert elicitation and may be appropriate for only a reduced set of species. In some cases, such as risk of ship strike or entanglement of North Atlantic right whales and effects on population growth, or risk functions associated with PTS/TTS and exposure context, risk functions are relatively well described. The group recommended that, when this data exist, DFO should avoid using the parameters and calculations of Box C and instead use the existing data, even if it results in the collapse of several parameters into a single one. The authors agreed that this should be the preferred approach where better data exist, but that the CERAF approach is designed to estimate these risk functions for CPs when such information does not exist.

The Chair reminded the group that one of the goals with this framework was to deal with cumulative effects, and this is where we get into more complex issues.

The group acknowledged that there is no equivalent approach that has been proposed and tested so it is unclear how it will perform. Therefore, it is recommended that the approach be tested with a case study using a specific MDP. This would also allow for testing the CERAF's applicability, identifying the most influential factors and effects of uncertainty, and thus areas where data are the most needed. Several in the group expressed concern that cumulating MDP-related effects without an upper constraint could result in estimated total harm exceeding population size. The authors responded that this emphasized the need for a reality check at each step in the evaluation process. It was suggested that an approach combining the proposed approach with a constrained total harm might be worth exploring.

The group concluded that the purpose of the CERAF could vary depending on the level of data available for a CP. It may be that the approach can be used fully only for a handful of circumstances where data are adequate for calculating impact magnitude. However, the group felt it can and should also be used as a scenario-testing tool or sensitivity analysis, analogous to a population viability model, where effect sizes are estimated for different values of the various parameters and level of uncertainty, or for determining how great an effect can become before regulators need to be concerned. An adaptive management cycle would be to identify the components that drive the uncertainty in order to identify which knowledge gaps are the most important to address.

Another suggestion was to use part of the stressor-specific sensitivity index (SSSI) estimation process from Box B (Figure 1), to highlight CPs that need to be more fully assessed. For instance, if there is significant MDP activity overlap with an important habitat or critical period, then more effort should be put into populating the parameters for Box C and assessing the risk fully.

There was a consensus that there is subjectivity in some of the categorization using the factor-mediated risk analysis, and that this weakness of the CERAF should be flagged clearly. In the SSSI calculation, it was also recommended that the authors review the terminology for “exacerbating factors” as it seems to imply catastrophic effects, whereas what was intended was synergism. Originally, the term was “aggravating factors” and the group agreed that this was a better term to use.

It was noted that net harm (i.e., number of animals with significant effects on their vital rates) should be rounded up, as it is illogical to kill 0.5 individuals. This approach is also more precautionary. The authors also pointed out that some animals may be accounted for multiple times under multiple effects. This additive approach was also meant to be precautionary.

There was a discussion on the most appropriate metric to use in the risk analysis to quantify the number of animal exposures. The authors proposed average densities as a starting point, with a weighting factor P (potential density) in cases where the total abundance in a given area is known. The group cautioned that the current terminology for P may lead to the perception of this quantity being a scientifically unfounded estimate (guesstimate) , while in reality P may actually be one of the things we do know and represents one of the most important columns in the table. There were suggestions to replace average density by actual abundance, however, it was pointed out that in data-deficient cases, average density might be the only data and thus, relevant to the CERAF. This point could be further clarified by specifying that the mean animal density is not just a simple density calculation but that it includes turnover, relative group size.

In calculating the base rate of exposure (R) using the ZOI, it was pointed out that because of the way noise attenuates, using a 50% base rate of exposure (R = 0.5) may significantly underestimate the number of animals exposed. By applying a step function, for example, as done in the California seismic study (Wood et al. 2012), with 10% at radius *x*, 50% at radius *y*, and 90% at radius *z*, the calculation might be less prone to this bias.

RISK ANALYSIS – SHIP STRIKE RISK MODEL (BOX C)

Presenter: Jack Lawson and Véronique Lesage, DFO (Newfoundland & Labrador and Québec Region)

Summary: Ship strike resulting from vessel activities associated with MDPs has the potential to have significant negative impacts on populations of marine mammals and sea turtles. An approach was proposed to estimate the number of animals that might suffer lethal effects after being struck by a vessel. This approach considered the number of vessel-animal intersection events during transits, amended by a recent study that demonstrated the influence of hydrodynamic features of a large moving vessel on animals that are not struck by the bow of the ship, but could be drawn into the hull and propellers as it passes. This estimate was further modified by incorporating variables to account for the probability of a ship strike being fatal as a function of vessel speed, based on a logistic regression analysis of data on whales struck by ships.

There were a number of qualitative, species- and vessel-specific risk factors that could be cumulated into a single species-specific sensitivity index that could then be input to the larger DFO risk assessment framework (Working Paper 2).

It appears that there are few monitoring and mitigation approaches that are likely to reduce the risk of ship strike for marine mammals and sea turtles. Reducing vessel speed, and reducing spatial overlap between vessels and marine mammals and sea turtles, were considered to be two of the best approaches.

Discussion: The group felt that the proposed approach to estimating collision risk is conceptually good, and that the addition of modifiers to modulate collision risk is appropriate. The group also felt that it would have been useful to present an example where the model was applied fully.

There was agreement that vessel speed is a key element as this seems the most important factor causing fatality. A recent study (Conn and Silber 2013) that included several new records of serious injury strikes at lower vessel speeds, modified the existing relationship between lethality and strike speed to one that is less extreme than that used previously (Vanderlaan and Taggart 2007). A more careful examination of the data to support the two functions might be warranted. For instance, is it more likely that the probability of being struck by a stationary vessel is 20% as indicated in the earlier model, or 0% as indicated by the new model? Fitting the shape of the curve was highly contingent on the belief of the boundaries being 1 and 0. It was pointed out that stationary ships with propulsion systems engaged, or using dynamic positioning, may still inflict injury or cause death to marine mammals that encounter the thrust units, thus the ship “strike” probability at 0 speed is probably small, but not 0. Knowing also that dead whales floating at the sea surface are struck by ships, it is likely that if these were included as true ship strike data, a very different relationship could be derived and the 50% chance of lethality could shift significantly. It was pointed out that there are very few reports of ship strikes in the Canadian Arctic and whether this is due to under-reporting is unclear. Therefore, using area-specific information might be problematic, particularly for the Arctic. The lack of full necropsies in most regions of Canada is also problematic in correctly documenting ship strike related fatalities.

There was agreement that the list of factors to consider in qualifying the modifiers to modulate collision risk is not exhaustive, and their relative importance may vary between species, age classes, social context, etc. There might be useful information to be gathered from line-transect shipboard surveys about attraction versus avoidance of vessels by the various species that could be integrated into the model to populate the behavioural aspect of collision risk. The authors indicated that the proposed model does incorporate this type of information in assessing collision risk.

The authors recognized that the modifiers, as currently proposed, qualify the relative sensitivity to ship strike, but do not quantitatively assess the modulated risk.

It was pointed out that the proposed model (Lawson and Lesage unpublished[3]) assumes an even distribution of ships whereas in fact, ships often follow specific routes and thus their distribution is uneven. The authors acknowledged this, and indicated that in cases where routes are known, then marine mammal densities specific to the expected area of transit should be used, if available. Ideally, the model would be based on the relative distribution of the vessel traffic versus the animals, to account for clustering of animals (and ships).

Chion et al. (2012) developed a collision-risk model for the St. Lawrence Estuary. After verification, this model will be available via the web as an unpublished report, in French.

[3] Lawson, J.W., Lesage, V. (2016). Modelling ship strike risks for marine mammals and sea turtles. DFO Can. Sci. Advis. Sec. Unpublished manuscript (8818).

EVALUATING RISKS (BOX D)

The proposed approach requires the calculation of two likelihood components. The first represents the likelihood that a stressor will result from activities of the proposed MDP (L_s) (e.g., chance of noise in excess of threshold causing PTS), while the second represents the likelihood of the stressor causing an effect (L_e).

This suggestion led to a wider discussion on the terminology and structure of the table presenting likelihood scores and definitions, as the proposed definitions were thought to include both data limitation (i.e., what is the likelihood that that data are known) and L_s. There was also an impression that in calculating net harm, there is some component of likelihood that is already included when calculating the fraction of animals exposed that would incur effects. This discussion also led to comments on the appropriateness of using two different types of likelihood (i.e., L_e and L_s). The authors provided clarifications on the two components of the likelihood: (1) likelihood of a stressor with characteristics leading to the defined effect arising from the MDP (L_s) (e.g., chance of noise in excess of threshold for causing PTS, or of an oil spill >700 tonnes), and (2) the likelihood of the stressor causing an effect (L_e) (e.g., chance for an oil spill to cause the death of a killer whale or sea otter, chance of noise in excess of 120 dB re 1 uPa_{rms} of causing disturbance). It was suggested the authors change “L_s” to “likelihood of occurrence” (L_o), and combine its components into a single likelihood.

The group felt that the framework could be simplified by modification of step 4 (risk evaluation) to use scales that are more intuitive. The authors indicated that the scales ranged from 0 to 5 for 3 reasons: 1) to allow impact and likelihood factors to be combined mathematically, 2) to have a uniform scale among MDPs, and 3) to capture the magnitude change between 1 and 5. Managers in the group felt it would be easier to use raw numbers of potential harm, or scales ranging from 0-1 to capture percentage (impact) or probability (likelihood), or scales ranging from 1 to 100. Graph axis labels could be adjusted so that each tick retained the intended magnitude. Also, by expressing impact as a proportion of TAH, the CERAF might better capture uncertainty as a range. What is considered low, medium and high magnitude factors will be left to the managers to decide at another stage in the MDP evaluation process.

In combining impact magnitude (N of individuals harmed) and likelihood, there is a need to determine when (i.e., at which level of likelihood) harm is deemed probable and if so, when it should start to be cumulated formally to be compared to TAH. For instance, a catastrophic event may remove a lot of animals, but since L_o is very low, then net harm for this stressor may not be dealt with the same way and so may not be formally cumulated in total harm for an MDP. The group presumed that a manager would welcome having access to a probability distribution of animal impacts, while discriminating between *possible* and *expected* impact (e.g., oil spill is included in *possible* impacts, but likely excluded from *expected* impacts).

When scoring the L_e (Table 7 in Lesage et al. 2016), there were concerns over the terminology used for L=1 (“very limited data demonstrating the mechanism of effects”) which the group suggested the authors replace with “very limited data available, so the effects are unknown”.

The authors pointed out that there was no attempt to define the heat map colours associated with impact magnitude. This scale would be defined by management, and based on the ecological relevance of the expected magnitudes.

TREATING RISKS – MITIGATION AND MONITORING (BOX E)

It was suggested that the authors incorporate mitigation near the start of Box C rather than considering it separately (see "General Comments on The Proposed Approach", above). However, the group concluded that it is useful to keep mitigation/monitoring as a separate step to show the added benefit of the mitigation measures. The purpose of the initial run through the CERAF is to identify and understand the activity risks without mitigation. Regulators at the workshop stated that it is a standard requirement in DFO to produce assessments transparently with and without mitigation measures, and show both sets of impact estimates.

ACCOUNTING FOR UNCERTAINTY

The group agreed that more clarity is needed in the document and framework for presenting sources of uncertainty at each step transparently, as well as the mechanics for cumulating it, so that a manager can understand where the uncertainty lies. A possibility is to use Table 5 scores as a divisor of likelihood, as done for impacts, but there might be other and simpler ways to account for this. Participants at the meeting suggested that managers, in general, like to have an estimate of uncertainty that is as quantitative as possible, and when not possible, at very least a qualitative statement about uncertainty.

Along the same lines, it was suggested that the authors revisit Table 7 to possibly reverse the scale and to determine how much data quality (Table 5) was already incorporated in defining the likelihood (see Lesage et al. 2016). Ideally, it could be a table that looks at both data availability and the uncertainty of the results.

REVIEW OF DRAFT SCIENTIFIC ADVISORY REPORT

Presenter: Andrea White, DFO (National Capital Region)

Summary: The structure of the Science Advisory Report (SAR), and outline of the summary bullets were presented to the group. It was agreed that there would be four main products out of this meeting, including the proceedings, the SAR, and two research documents. One of the research documents would summarize the framework and the other the approach for ship strike risk estimates. The document presented by Dr. Gomez will not be turned into a research document, but will instead be updated based on group feedback and submitted as a primary journal publication.

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APPENDIX 1: TERMS OF REFERENCE

Review of a Risk-Based Framework for assessing Cumulative Impacts of Marine Development Projects (MDPs) on Marine Mammals and Turtles

National Peer Review – National Capital Region

March 3-5, 2015
Ottawa, Ontario

Chairperson: Dr. Garry Stenson

Context

The Department of Fisheries and Oceans (DFO) has requested the development of a national approach and minimum standards for assessing the impacts of Marine Development Projects (MDP) on marine mammals and sea turtles. In particular, clear guidance is needed as to the information required from proponents to assess impacts adequately, the criteria to determine probability and magnitude of impacts, approaches to the management of uncertainty, and ways to cumulate impacts at the population and regional levels.

There is a need for the industry, and a desire by Federal and Provincial/Territorial governments to ensure an efficient regulatory review process for MDP. However, the lack of clear guidance and a national approach to impact assessment may lead to a perception of inter-regional and inter-project inconsistency, and unfairness in the reviews, and often result in iterative dialogue and extended periods of review.

An initial international workshop was held by DFO in Quebec City in March 2014 to solicit opinions from experts with experience in impact assessment approaches to guide the development of the draft national risk-based framework. Topics discussed at this first workshop included aspects related to noise exposure as well as collision risks, including: (1) advances since Southall et al. (2007), and the most appropriate measurement methods and frequency weighting for assessing injury takes and behavioural responses to pulsed and non-pulsed sounds, (2) review models developed to assess collision risks, taking into account species-specific vulnerability criteria to determine probability and magnitude of impacts against population productivity, conservation status, and nature of the risk source, (3) identify means to incorporate uncertainty into the risk assessment framework, and to cumulate MDP impacts at population and regional levels, and (4) how these components could be incorporated into a framework.

Based on the discussions held during the first workshop, a final framework will be presented for formal peer-review by DFO and international experts in the field of acoustics, population dynamics, risk-assessment, cumulative impact assessment, and behavioural ecology. This scientific advice will become a national standard for DFO when assessing impacts of MDP on marine mammals, and be used to develop guidelines to the industry for addressing marine mammal issues in their Environmental Impact Statements (EISs). This standard might also provide the basis for similar efforts for other marine biota.

Objectives

1. Review the DFO draft framework to risk analysis and assessment (based on recommendations from the first workshop), and the proposed guidelines regarding the information required from proponents to assess impacts of MDPs adequately.
2. Review information on the criteria to determine the probability and magnitude of impacts from various stressors on marine mammals and sea turtles. Identify data gaps and proposed methods to address them.

3. Provide direction on methods to assess combined and cumulative impacts at the regional and population levels

Expected publications

- Science Advisory Report
- Proceedings document
- Two Research Documents

Participation

- Fisheries and Oceans Canada (DFO) (Oceans and Fisheries Policy, Ecosystems and Oceans Science, Fisheries Protection Program, Ecosystems and Fisheries Management, Species at Risk)
- Academic and other national and international scientific experts
- Offshore Petroleum Boards
- National Oceanic and Atmospheric Administration (NOAA)
- Joint Nature Conservation Committee (United Kingdom)
- Inuvialuit Joint Secretariat

APPENDIX 2: LIST OF PARTICIPANTS

Name	Affiliation
Solomon Amuno	Nunavut Impact Review Board (CAN)
Nicole Bouchard	DFO Species at Risk (CAN)
Dave Burley	C-Newfoundland Labrador Oil and Petroleum Board (CAN)
Chris Clark	Cornell University (USA)
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Martine Giangioppi	DFO Oceans (CAN)
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Garry Stenson	DFO Science (Chairperson) (CAN)
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Mark Tasker	Joint Nature Conservation Committee (UK)
Dominic Tollit	Sea Mammal Research Unit (CAN)
David Wiley	NOAA - Stellwagen Bank National Marine Sanctuary (USA)
Rob Williams	University of British Columbia (CAN)
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Andrea White	DFO Science (CAN)
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APPENDIX 3: AGENDA

Canadian Science Advisory Secretariat International Peer Review
Risk-Based Framework for Assessing Cumulative Impacts of Marine Development Projects on Marine Mammals and Sea Turtles in Canada

March 3-5, 2015

Lord Elgin Hotel
Ottawa, ON

Chairperson: Dr. Garry Stenson

Daily schedule plan as follows, but allow for some flexibility

DAY 1 – Tuesday March 3

Time	**Topic**	**Presenter**
8:00 – 8:30	Introductions and Outline of Task • Context for the Review • Review of Terms of Reference • Review of CSAS process and guidelines • Review of Agenda	Chair – Garry Stenson
8:30 – 9:00	Legal Context to Impact Assessment in Canada	Jack Lawson
9:00 – 9:15	Threshold Setting for PTS, TTS & Disturbance (NOAA) • Update on Initiatives	Amy Scholik-Schlomer, NOAA
9:40 – 10:15	Threshold Setting for Noise Exposure – A Harbour Porpoise Perspective • Additional Views on Best Approach	Andrew Wright, George Mason Univ.
10:15 – 10:40	*Health Break*	
10:40 – 12:30	Accounting for Behavioural Context in Threshold Setting for Assessing Disturbance • Received Levels and Context • Results for a Subset of Species • Severity Scale from Southall *et al.* • Dose-Response Curves	Catalina Gomez, DFO
12:30 – 14:00	*Lunch*	
14:00 – 15:00	Assessing Cumulative Noise Exposure • Simple to More Complex Models • Group discussion o Cumulating Pulsed vs. Non-pulsed Sounds Operationalization	Christine Erbe, Curtin Univ.
15:00 – 15:30	*Health Break*	

Time	Topic	Presenter
15:30 – 17:15	Implementation of Population Consequences of Disturbance with Imperfect Knowledge • Cumulative Effects Caused by Repeated Behavioural Disruption • Energetic Costs of Disruption Linked to Population Viability	David Lusseau, Univ. of Aberdeen
17:15 – 17:30	Wrap Up	Chair – Garry Stenson

DAY 2 – Wednesday March 4

Time	Topic	Presenter
8:00 – 8:10	Key points from Day One, and Discussion of Day Two Goals	Chair – Garry Stenson
8:10 – 8:30	Review of alternative to assessing behavioural effects	Catalina Gomez, DFO

8:30 – 9:40	Assessing Masking
	• Simple to more complex models
	• Group discussion
	    o Threshold setting for Masking
	    o Accommodation for Loss of Acoustic Space
	• Operationalization
		Chris Clark, Cornell Univ.

9:40 – 10:00	Overview of the Cumulative Risk Assessment Process and Summary Framework Model • Approaches to Cumulative Risk Assessment • Major Steps & Definitions • Incorporating CP Vulnerability Risk and Sensitivity to Stressors • Combining & Cumulating Lethal & Non-Lethal Risks • Incorporating Uncertainty • Accounting for Efficiency of Mitigation Measures • Cumulating Risks from Multiple Projects	Veronique Lesage, DFO
10:00 – 10:15	*Health Break*	
10:15 – 13:00	Overview of the Cumulative Risk Assessment Process and Summary Framework Model (Continued)	Veronique Lesage, DFO
13:00 – 14:15	*Lunch*	
14:15 – 15:00	Overview of the Cumulative Risk Assessment Process and Summary Framework Model • Group Discussion (Continued)	Veronique Lesage, DFO

Time	Topic	Presenter
15:00 – 15:45	Threshold Setting in the Canadian framework	Veronique Lesage, DFO
15:45 – 16:00	*Health Break*	
16:00 – 17:30	Accounting for CP Vulnerability in Setting Acceptable Harm • PBR as a Measure of Risk to Recovery • Models for Calculating Vulnerability Index (VI) • Factoring VI in Risk Evaluation • Group Discussion o Best Options o Defining Vulnerability Criteria	Veronique Lesage, DFO
17:30 – 17:35	Wrap Up of Day Two	Chair – Garry Stenson

DAY 3 – Thursday March 5

Time	Topic	Presenter
8:15- 8:40	Summary of the main steps of the Framework	Chair – Garry Stenson
8:40 – 10:10	Accounting for Stressor-Specific Sensitivity • Models for Calculating Sensitivity • Factoring Sensitivity into Risk Analysis • Sensitivity to Collision Risk and Behavioural Disturbance from Excess Noise as Examples • Group Discussion o Ways of Factoring Stressor Sensitivity into Risk Analysis o Modulating Severity Scale for Disturbance with Sensitivity o Defining Sensitivity Criteria for Stressors and Effects	Veronique Lesage, DFO
10:10 – 10:40	*Health Break*	
10:40 – 11:30	Modelling and Assessing Ship Collision Risk • Components of the DFO Model • Collision Risk Index • Discussion o Integrating Collision Factors Into Framework o Accounting for Uncertainty and Context	Jack Lawson
11:30 – 12:20	Risk Evaluation • Calculating Impact and Likelihood Scores • Accounting for Uncertainty	Veronique Lesage, DFO

Time	Topic	Presenter
12:20 – 13:45	*Lunch*	
13:45 – 15:15	Review of alternative to assessing behavioural effects	Catalina Gomez, DFO
15:15 – 15:50	Discussion About the Validity of the Proposed Framework	Garry Stenson, Chair
15:50 – 16:00	*Break*	
16:00 – 16:30	Review of Main Sections of Science Advisory Report	Andrea White, DFO
16:30 – 16:45	Wrap Up and Closing Remarks	Garry Stenson, Chair

APPENDIX 4: AN ALTERNATIVE APPROACH TO ACOUSTIC IMPACT ASSESSMENT NOT BASED ON RECEIVED-LEVEL OR BEHAVIOURAL RESPONSE

Catalina Gomez, Andrew Wright, Mark Tasker, Christopher Clark, Karin Forney, and Dominic Tollit

INTRODUCTION

It is clear from the review of over 300 studies (see presentation on March 3 at 10:40) that a generalized predictive model of acoustic impact, mediated via behavioural responses (i.e., via a linear severity scale), based upon received level (RL), is unlikely to be scientifically feasible. Even if it is, it would require a level of detail that would render any resulting model so complicated that it would be likely unworkable in a management setting.

This is because the best available information on the effects of underwater sounds on the behaviour of marine mammals is highly detailed, but does not necessarily provide clear consistent pressure/response relationships. As a result, such uncertain information cannot be used easily in generalized management frameworks as it would carry considerable risk of leading to inappropriate responses. Attempts to implement the best available information directly into management are therefore inadvisable.

Instead, management should use this scientific information to create a workable procedure that can be applied in a reasonably simple and transparent manner to achieve defined management objectives. However, any simplifying assumptions should be based on the best available science, with any of the uncertainties expressly noted and acknowledged.

Thus, in lieu of a behavioural response impact measure dependent entirely upon RL, we propose a variation of the European noise management model, which is based on the proportion of habitat lost to a species. However, it should be associated with an additional decision tree/set of questions that determine particular situations where there are known conditions that may exacerbate or alleviate impacts notably beyond the simple area-impact model. Even with the additional considerations, such a system takes into account that establishing any cumulative impact framework for noise impacts requires that management/social values determine the level of acceptable impact in a manner that can be scientifically measured (i.e., what is the acceptable magnitude of habitat loss?).

PART 1: PROPORTION OF HABITAT LOST IN TERMS OF TIME/AREA

When individuals/populations are exposed to noise, they can either stay or leave the area. In any case, there is a loss of physical or acoustic habitat. The decision to stay or leave the area is context-dependent and it will depend in part on whether there is alternative suitable habitat. For example, in many cases mysticetes do not move away from “noisy” environments and therefore, lose “pristine” acoustic habitat by staying, which can be measured as an acoustic impact footprint. In those cases, the masking footprint acts partly as a proxy for all sub-lethal impacts.

In this proposed framework, the proportion of habitat lost in terms of time/area is determined to be the larger of the following:

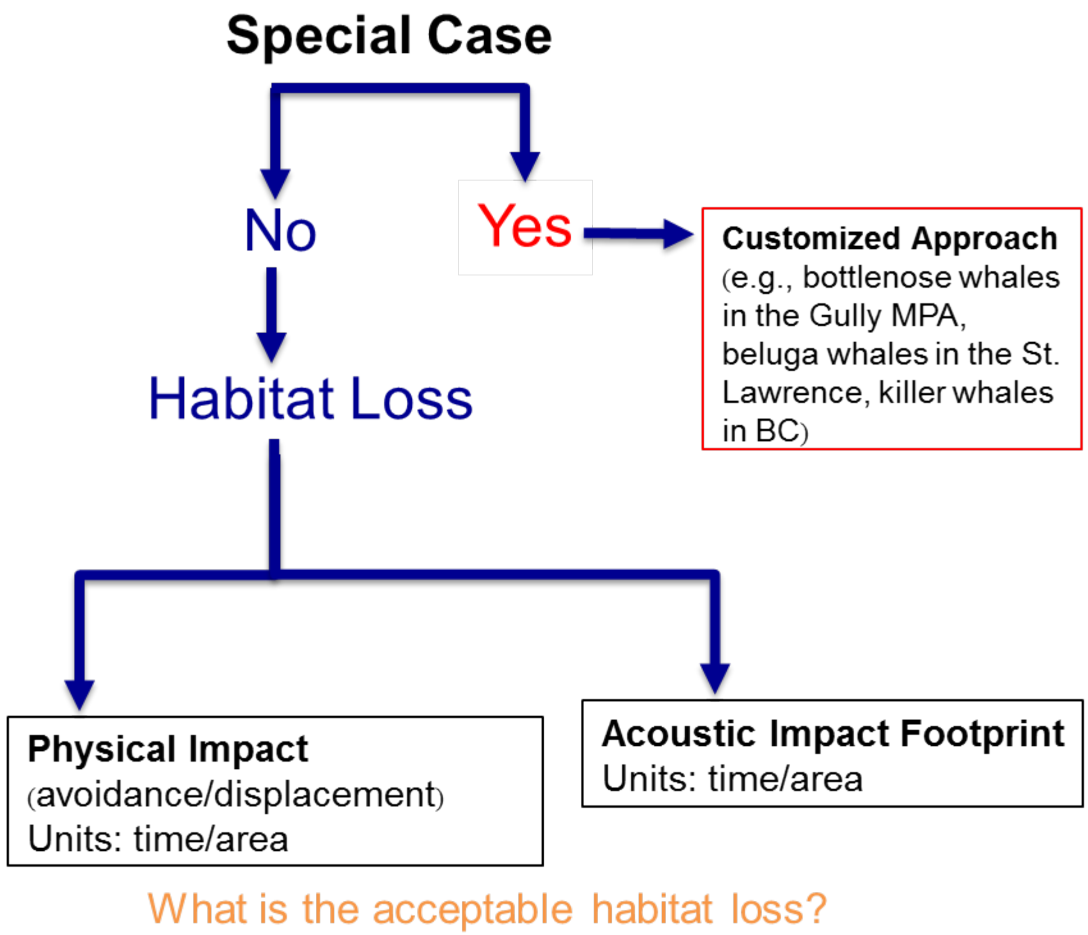
1. The avoidance area (based upon or extrapolated from empirically-observed avoidance in similar circumstances) – the model could be based upon a coarse spatial and temporal scale model that has caution built into it, which would require only a reasonable estimate of source level (SL) for a series of sound generating activities. This represents the loss of physical habitat;

2. The area over which acoustic impacts, such as behavioural responses, masking or stress responses, might be experienced in the event that animals do not exhibit avoidance. This represents the loss (or decline in quality) of acoustic habitat and could be determined in various ways, including, but not limited to:
    a. A dose-response curve for an appropriate sub-lethal impact against sensation level (closely tied to RL), if possible to construct for the given species;
    b. An approximation for onset of notable stress responses based on SL, perhaps extrapolated from human literature;
    c. An estimate of the area over which communication vocalizations with conspecifics are obscured (e.g., to 12 dB over natural ambient noise);
    d. An estimate of the area over which sounds of particular interest and with specific fitness consequences (e.g., predators, prey) are obscured (e.g., to 6dB over natural ambient noise, reflecting apparent enhanced responses to lower-level exposures); or
    e. An estimate of exposure /impact based on simpler signal-to-noise ratios or energy (or peak level) over hearing threshold.

PART 2: CASE-BY-CASE CONSIDERATION OF SPECIAL CASES

This is a set of questions that would direct managers back to the known science in situations where the simple measure of habitat loss is unlikely to accurately reflect the degree of impact to a CP. Such special consideration could (and probably should) be run concurrently with the habitat loss analysis described above (Part 1). An answer of ‘yes’ to any of the following would trigger a more detailed consideration of such special cases:

1. Is species known to be sensitive / resilient to particular sounds (e.g., beaked whales and mid-frequency naval sonar, high Arctic beluga whales and ice-breakers, harbour porpoises, and drilling noise)?
2. Could acoustic exposures be changed by bathymetry?
3. Does the population have a small range in relation to impact area (e.g., beluga whales in the St. Lawrence estuary)?
4. Is there any other suitable habitat nearby (e.g., resident killer whales in British Columbia and distribution of Chinook salmon?)
5. Are there other notable anthropogenic or natural threats nearby in potential alternative habitat if animals are displaced (e.g., bycatch, shipping lanes, predators, etc.)? In this particular case, habitat loss is combined with some of the special case considerations. For instance, total impact may be higher than expected if displaced animals move to low-quality alternatives (e.g., there could be heavily fished areas with gillnets that increase entanglement risk, or shipping lanes that might increase collision risk).
6. Are there critical risk factors that they will be exposed to? (e.g., reduced foraging success, bycatch in fisheries, mass stranding, increased predations?)



Appendix Figure 1. Conceptual model of an alternative framework approach to behavioural-received level noise impact assessment. Injury and TTS could be dealt with primarily through mitigation in addition to physical and/or acoustic habitat loss.

THE ROLE OF MITIGATION

Most current mitigation methodologies for the effects of noise are based on separating the noise source from the receivers (i.e. animals). For example, ramp-ups (or soft starts) during seismic activities are used to gradually increase sound levels and deter animals from entering the area near the higher energy sound source when it becomes fully operational. Such mitigation is primarily aimed at minimizing direct physiological harm by displacing animals, though may have other effects on the organisms. In an ideal world, risk should be reduced by minimizing harmful noise production, but this is not always possible. In any case, mitigation must be effective at reducing sound exposures in a manner than can be easily implemented on site. In this proposed alternative framework, injury and TTS could be dealt with primarily through mitigation, although it can, of course, be considered in addition to physical and/or acoustic habitat loss.