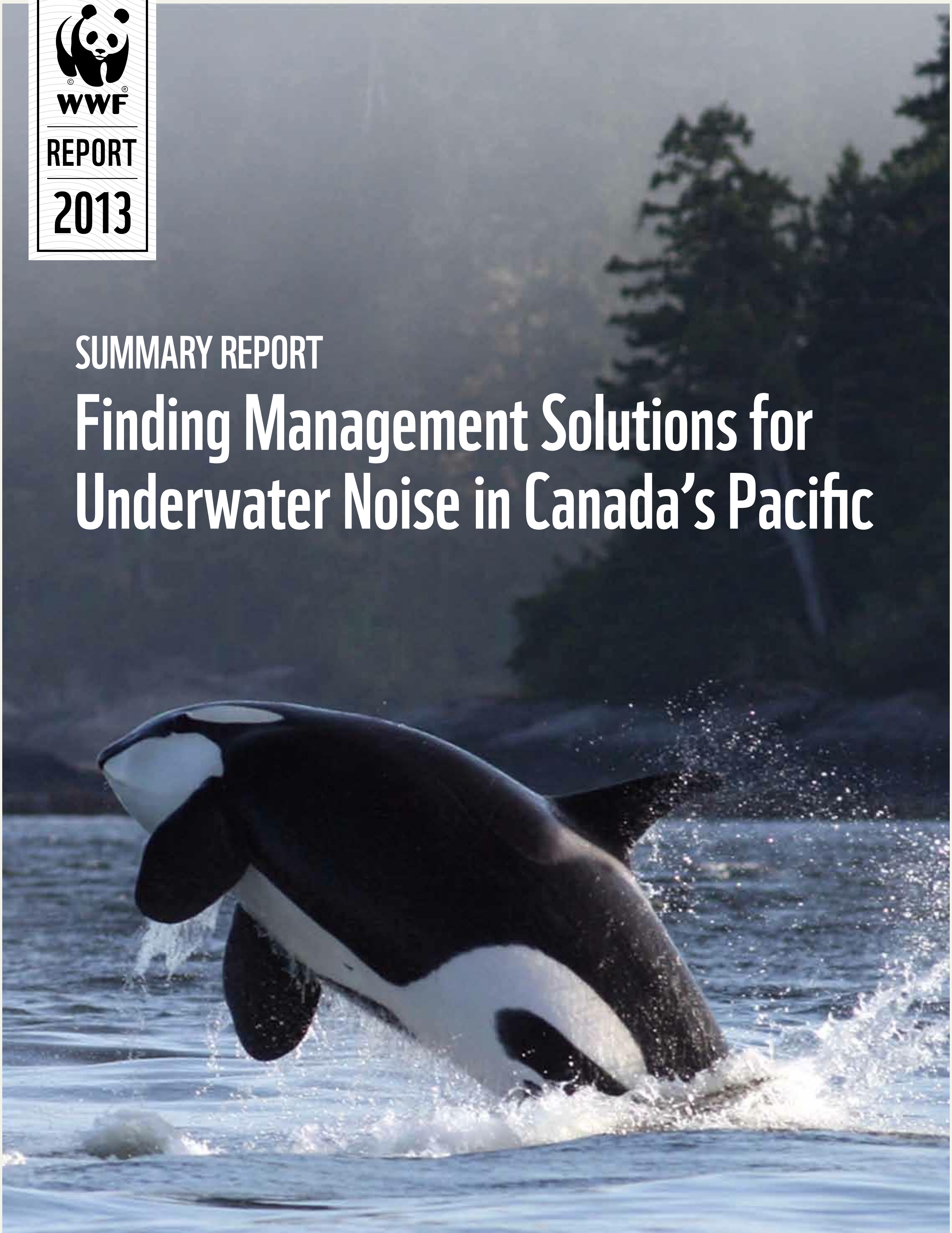
WWF

REPORT 2013

SUMMARY REPORT

Finding Management Solutions for Underwater Noise in Canada's Pacific



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EXECUTIVE SUMMARY

Recognizing that underwater noise is an emerging threat to the health of marine ecosystems, WWF Canada hosted a two-day workshop for marine planners and regulators to help find solutions for underwater noise management in Pacific Canada. The workshop provided a forum for 45 participants to discuss various methods for minimizing and mitigating underwater noise, and to develop tools for planners and regulators to draw from as they move forward in planning processes, reviewing environmental assessments, and recovery planning for species listed under the *Species at Risk Act* (SARA).

The workshop began with general presentations providing background on understanding underwater sound, why it is an issue for marine animals, and current and proposed projects that will have implications for increasing underwater noise on the north and central coast of British Columbia. This was followed by a series of presentations on the tools that are currently available to manage noise in Canada and elsewhere, particularly marine protected areas, the EU Marine Strategy Framework Directive, mechanisms under the *Species At Risk Act*, lessons learned from the United States and by the Port of Metro Vancouver as it moves ahead in developing incentive programs to address pollution from ports and ships. On Day 2, presentations on frameworks for cumulative impacts and mitigation/compensation provided the basis for discussion of how best to decide which approaches are most appropriate for evaluating proposals on a case-by-case basis. The incentive-based Green Marine program and the role of the IMO in reducing shipping noise was also discussed, as well as other methods of reducing shipping and pile driving noise.

Following the presentations, the group divided into four breakout groups to discuss 1) the concept of acoustic reserves on the coast, 2) noise standards and the role of incentivizing quieting, 3) how to incorporate noise into marine planning processes, and 4) what can be done to reduce noise in British Columbia's waters within the next 5 years. A number of recommendations for planners and managers were extracted from the presentations and discussions, and they are included here and framed around translating science into policy; impact assessments; regulation; marine plans; acoustic monitoring; acoustic quieting and marine protected areas; voluntary and incentive programs; and education and communication. Recognizing that there are multiple pathways to manage underwater noise as a stressor on marine life, it is precautionary to implement operational and technological quietening measures now, and to incorporate the quality of the acoustic environment as a valued ecosystem component in marine planning processes. Key recommendations of the workshop and its breakout groups were:

Recommendation 1: More work must be done to translate the science of underwater noise into policy and regulations to guide management decisions.

Recommendation 2: A new DFO policy on underwater noise, addressing projects' full acoustical footprints and incorporating cumulative impacts of multiple developments, should be developed to guide project proponents and regulatory decision makers.

Recommendation 3: Revise and implement new regulations at different scales to improve underwater noise management.

Recommendation 4: Marine plans should specify noise objectives, and set cumulative noise caps regionally. They should in part do this by engaging the local community to ensure grass roots support.

Recommendation 5: Noise monitoring should be expanded off the coast of BC.

Recommendation 6: A quietened or quiet area, such as within an existing or proposed MPA in BC, should be designated in Canada's Pacific.

Recommendation 7: Existing industry and port environmental incentive programs should be expanded to include underwater noise criteria.

Recommendation 8: Public and industry education programs should be developed about the impacts of underwater noise on marine life, and possible mitigation measures

Background Documents

Two background documents were sent out to participants prior to the workshop –*A Primer on Underwater Sound and Noise*, and an *Overview of Ocean Noise Regulation in Canada*. They are attached as Appendices to this Report and are also available separately at http://www.wwf.ca/newsroom/reports/oceans/

ACKNOWLEDGEMENTS

WWF Canada is grateful to everyone who attended the workshop and gave willingly of their ideas and time to make the event a success, with a special thank you to each of the presenters – Andrea Ahrens, Mike Ambach, Lance Barrett-Lennard, Darrel Desjardin, Kathy Heise, Michael Jasny, Jack Lawson, Cathryn Murray, Linda Nowlan, Jason Scherr, Sheila Thornton, Lindy Weilgart and Janie Wray, and to Richard Holt who took on the role of facilitator during a group discussion on the IMO. We also appreciate those who took a lead in the panel discussion following Erich Hoyt's presentation on marine protected areas: Doug Biffard, Erin Ashe, Jason Thompson, and Andrew Wright.

There are many who contribute to the success of any workshop, but we are especially indebted to Kathy Heise, who ably carried out overall organisation and convening, and compiling of the initial report. Lance Barrett-Lennard brainstormed with us during the development of the agenda, and during the workshop took on marshalling the 40+ people in the room as the convenor, yet still found the time and energy to give a very interesting presentation on alternatives to current mitigation practices. Equally important were the efforts of Sydney Gudmundson, who handled so many of the detailed logistics of the workshop, and always with a smile. Thanks also go to Sydney for copy editing this report. Louise Blight and Linda Nowlan also edited the report, and helped to develop the agenda with assistance from Michael Jasny and Lance Barrett-Lennard. Erich Hoyt travelled far to provide us with a much broader understanding of global initiatives in developing MPAs, and how noise considerations could be brought into marine planning processes. Lindy Weilgart gave freely of her time, providing invaluable expertise on underwater acoustics. She and Ross Chapman kindly reviewed an earlier draft of the underwater noise backgrounder sent out to participants prior to the workshop. We also appreciate the efforts of all the WWF staff who took notes at the meeting: Selina Agbayani, Mike Ambach, Louise Blight, Peter Ewins, Cathryn Murray, Linda Nowlan and Tonya Wimmer, as well as Max Ritts from the UBC Dept. of Geography. The catering staff at the Vancouver Aquarium fed us very well, giving us energy to keep engaged for a very full two days. Special thanks to Cetacealab for the images used in this report, and to Andrew Wright for his comments on it.

And most importantly, this workshop would not have taken place without the generous support of the Margaret A. Cargill Foundation, for which we are all very grateful.

c. forwhales.org

INTRODUCTION

WWF-Canada hosted its first workshop on Ocean Noise in Canada's Pacific on January 31-February 1, 2012 (Heise and Alidina, 2012). The workshop, held in Vancouver, British Columbia (BC), was designed to obtain a better understanding of the existing acoustic monitoring and research on Canada's west coast, as well as sources of anthropogenic underwater noise and its related conservation concerns. The workshop was successful in developing a better network among the ocean noise community, and these efforts are continuing. Two medium to long term actions arose from the meeting: to provide input on anthropogenic noise into regional marine protected area (MPA) network planning, and to provide management and policy recommendations for noise mitigation.

Given that marine planning processes are already well underway in BC (e.g., Pacific North Coast Integrated Management Area (PNCIMA), the Marine Planning Partnership for the North Pacific Coast (MaPP), and various marine protected areas (MPAs)) this is an important time to raise awareness around the effects of noise on marine life and its potential detrimental effects on ecosystem function.

Following up on the recommendations from the first workshop, WWF-Canada convened a second workshop, "Finding Management Solutions for Ocean Noise in Canada's Pacific", held on June 6 and 7, 2013, at the Vancouver Aquarium. The goal of the workshop was to provide a forum for discussing management and regulatory approaches for minimizing and mitigating underwater noise, particularly those relevant to Pacific Canada, and to develop guidance tools for marine planners and regulators. The objectives of the workshop were to:

- Review sources of anthropogenic noise and its effects on marine animals;
- Discuss current and alternative mitigation methods for shipping noise (primarily) and pile driving (to a lesser extent) in Canada;
- Examine current Canadian regulatory standards;
- Examine voluntary standards (e.g., IMO guidelines on shipping noise, port incentives) and discuss how they might fit into noise management in BC;
- Examine case histories of noise management from other areas (e.g., EU Marine Strategy Framework Directive); and
- Determine how best to bring underwater noise management into marine planning processes.

To facilitate engagement and interaction amongst all participants, the workshop was relatively small (45 people). Participants had diverse backgrounds: marine planning, policy, regulation, acoustics and/or cetacean biology, port operations, and industrial development.

The workshop was organized around presentations, which were followed by group discussions. It began with a backgrounder on underwater noise, followed by current issues facing BC's north and central coasts. This was followed by presentations on potential tools to manage noise, such as MPAs, the EU Marine Strategy Framework Directive (MSFD), the federal *Species at Risk Act* (SARA) and port-based incentive programmes.
On Day 2, presentations and discussions focused on cumulative impacts and mitigation/compensation frameworks, and the role of the shipping industry in contributing to mitigation measures for underwater noise. This was followed by four concurrent breakout sessions, and to close the workshop, each breakout group reported back to the larger audience, highlighting the main points of their discussions. The topics of the breakout groups were:

- Acoustic reserves as a strategy to reduce the impacts of underwater noise: where should they be located? Are they appropriate for the Douglas Channel/Caamaño Sound area?
- Noise standards for BC and Canada: what is appropriate? What role is there for incentivizing reduction or quieting technologies?
- Marine plan implementation. Given current processes, how should PNCIMA, MaPP, and the BC government incorporate underwater noise considerations in development plans? What would be the priorities?
- What could we achieve in Canada's Pacific over the next 5 years?

The following pages contain extended abstracts written by the presenters, followed by a synthesis of the breakout group discussions based on notes taken by WWF rapporteurs. The concluding recommendations are extracted from various presentations and discussions, and are organized by topic: translating science into policy; impact assessments; regulation; marine plans; acoustic monitoring; acoustic quieting and marine protected areas; voluntary and incentive programs; and education and communication.

Humpback whales use sound to coordinate bubble-net feeding. c. forwhales.org

References:

Heise, K. and H.M. Alidina (2012). Summary report: ocean noise in Canada's Pacific workshop, January 31- February 1 2012, Vancouver, BC. WWF-Canada, Vancouver. Available at www.wwf.ca/newsroom/reports/oceans/

PRESENTATIONS

DAY 1 – 6 JUNE 2013

I - SETTING THE STAGE

Sound 101: A Backgrounder on Underwater Noise

Kathy Heise, Vancouver Aquarium

This presentation was intended for those who knew relatively little about sound, the differences between sound in water relative to sound in air, and some of the more common sources of underwater man-made sounds (anthropogenic noise). It was based on the background document "A Primer on Underwater Sound and Noise" appended to this document (Appendix 3) and available as a separate document at http://www.wwf.ca/newsroom/reports/oceans/.

The ears of all marine vertebrates are functionally similar to those of terrestrial vertebrates, including humans (Fay and Popper, 2000). Many marine animals use sound in much the way that terrestrial animals use light – to detect predators and prey, to communicate, and to navigate – it is their primary underwater sensory modality. Sound waves travel much faster in water (~1,500 m/s) than in air (~300 m/s), and low frequency sound waves travel significantly further than high frequency sounds. Underwater, listening is a very effective way for an animal to acquire information about its environment.

The amplitude (loudness), frequency (pitch) and duration are key characteristics that are used to describe sounds. Sounds that are continuous, such as boat noise, are described as chronic or non-pulsed, whereas sounds that are of short duration, such as an explosion, or of repeated short duration, such as pile driving or airgun firing, are pulsed (or acute or intermittent). A sound that occurs within a narrow range of frequencies is described as narrowband, whereas sounds that occur across a wide range are referred to as broadband. Most of the energy in shipping noise, and in baleen whale communication signals, lies in frequencies below 1000 hertz (Hz). Sounds below 100 Hz can travel 1000 km in open water with very little attenuation. To describe sounds quantitatively, the sound intensity level or pressure level is described relative to a fixed reference intensity of pressure. The reference intensity is different between water and air, therefore sound intensity or pressure measurements are not comparable between the two media. The unit is the decibel (dB), and in water, the intensity is typically expressed as dB re 1 µPa @ 1 m.

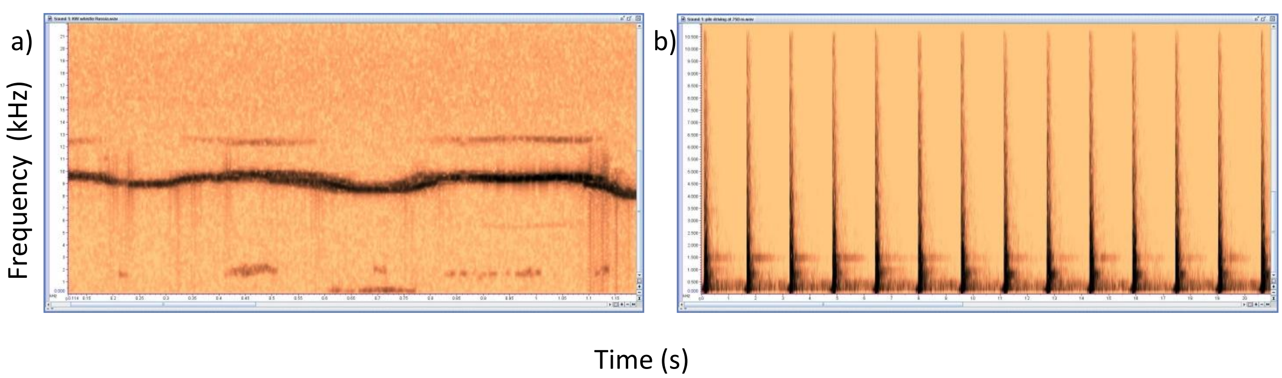

Figure 1. Spectrograms of a) the continuous and narrowband sound of a killer whale whistle, and b) the pulsed and broadband sound of pile driving. Courtesy of Kathy Heise.

There are no widely accepted international standards for reporting sound pressure levels (SPL, units are dB re 1 µPa) and depending on how the pressure or energy is calculated or measured, the numerical value associated with a sound can vary significantly (by 20 dB or more). Peak amplitudes, peak-to-peak amplitudes and root mean square (rms) may all be used (Figure 2, and Table 1). Sound exposure levels (SEL) measure the total energy of a signal over time, and in water, the sound exposure units are dB re 1 µPa ·s. They can be used to compare sounds that are continuous, single, or multiple pulses, and can also be used to describe the cumulative exposure of a sound over the duration of a specified time period (Table 1). It is also important to note whether the sound energy is reported at the source (usually 1 m from the actual source), or is a received level. For sound sources larger than a few cm, the sound is produced over a distance greater than 1 m, so sources levels are modeled.

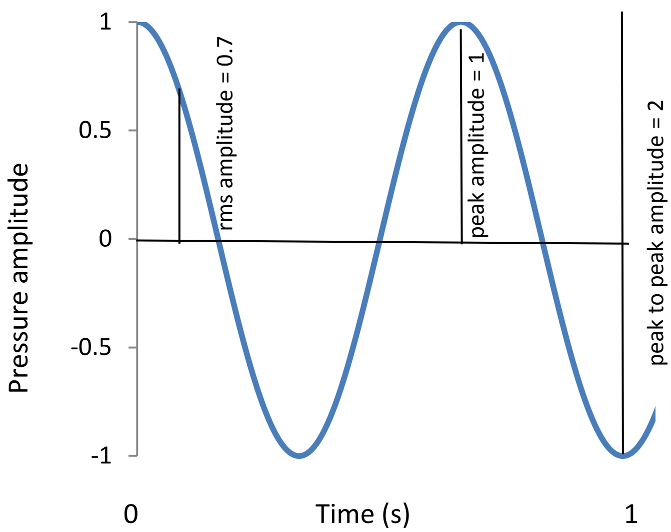

Figure 2. A waveform showing several ways of expressing the amplitude of a continuous sound. The root mean square (rms) amplitude is 0.8, the peak amplitude is 1 and the peak to peak amplitude is 2. Courtesy of Kathy Heise.

There are many naturally occurring loud sources of sound in the ocean, ranging from biological ones, such as sperm whale codas or blue whale calls, to abiotic sources such as wind and waves and underwater earthquakes. Whether a sound is considered noise depends on the perspective of the listener. For the purpose of this workshop, noise is considered to be anthropogenic (man-made) sounds that potentially may impact marine mammals, invertebrates and fish. Sources of noise on the BC coast include shipping, seismic surveys, military activities (e.g., sonar, torpedoes), vessel sonar, new and emerging technologies (e.g., AUVs, modems) and harbour activities (e.g., pile driving and dredging).

Anthropogenic noise can interfere with the ability of marine animals to forage, reproduce, avoid predators, communicate and navigate. It may cause behavioural changes, although these are often difficult to detect or interpret. It can mask important communication and echolocation signals and

Table 1. Noise levels from several types and diameters of marine piles, expressed in different metrics, modified from Rodkin and Reyff (2008).

Pile type (diameter)/ Hammer type	Distance from pile (m)	Peak sound pressure (dB re 1 μPa)	RMS sound pressure (db re 1 μPa)	SEL (dB re 1 $\mu Pa^2 \cdot s$)
Timber (0.3 m)/drop	10	177	165	157
Steel shell (0.3 m)/drop	10	177	165	152
Concrete (0.6 m)/impact	10	183	171	160
CISS (0.3 m)/impact	10	190	180	165
CISS (2.5 m)/impact	25	212	197	188

(CISS = Cast in steel shell piles = concrete piles within a steel shell)

reduce an animal's ability to listen passively for biologically meaningful sounds. Just as with humans, noise can cause physiological damage, including temporary and/or permanent threshold shifts in hearing ability. Because many marine vertebrates use sound the way terrestrial mammals use vision, anything that reduces their ability to acquire information about their environment may increase their risk of mortality. In certain conditions, high-energy underwater noise can result in direct mortality. A selection of recent literature on the effects of underwater noise on marine life is included in Heise (2013).

On the BC coast, the most common anthropogenic noise source is vessel traffic. Ambient or background noise levels have increased 2.5-3 dB per decade in the open Pacific, and much of this is attributed to increased commercial shipping (McDonald et al., 2006; Spence et al., 2007; Chapman and Price, 2011). Vessel noise is broadband, and generally the main source is cavitation caused by the rotation of the propeller. The faster a ship travels, the greater the cavitation (Spence et al., 2007; McKenna et al., 2013). There are numerous other sources of noise on a ship, and these are discussed in more detail in Heise (2013). We can expect as shipping traffic increases, overall ambient noise levels on the BC coast will also increase.

References

Chapman, N.R. and A. Price. 2011. Low frequency deep ocean ambient noise trend in the Northeast Pacific Ocean. J. Acoust. Soc. Am. Express Letters 129:EL161-EL165.

Fay, R. R., & A.N. Popper (2000). Evolution of hearing in vertebrates: the inner ears and processing. *Hearing research*, *149*(1), 1-10.

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McDonald, M.A., J.A. Hildebrand and S.M. Wiggins. 2006. Increases in deep ocean ambient noise in the northeast Pacific west of San Nicolas Island, California. J. Acoust. Soc. Am. 129:711-718.

McKenna, M.F., S.M. Wiggins and J.A. Hildebrand. 2013. Relationship between container ship underwater noise levels and ship design, operational and oceanographic conditions. Sci. Rep. 3. 1760; DOI:10.1038/srep01760.

Rodkin, R.B. and J. A. Reyff. 2008. Underwater sound from marine pile driving. Pages 138-140 *in* Hawkins, A.D., A.N. Popper, and M. Wahlberg (editors). International Conference on the effects of noise on aquatic life. Bioacoustics 17(1-3).

Spence, J., R. Fisher, M. Bahtiarian, L. Boroditsky et al. 2007. Review of existing and future potential treatments for reducing underwater sound from oil and gas industry. Noise Control Engineering Report to the Joint Industry Programme on E & P Sound and Marine Life. NCE Report 07-001. Accessed on May 22, 2013 at http://www.soundandmarinelife.org/Site/Products/NCE07-001_TreatmentsForUnderwaterSoundFromOil.pdf

Northern resident killer whales. c. forwhales.org

II - FRAMING THE ISSUES

Current and Proposed Projects with Underwater Noise: Implications for the North and Central Coast

Mike Ambach, WWF-Canada

The current trajectory of the marine transport industry in the North and Central Coast of British Columbia points to a 100% increase in large vessel traffic by 2020 with continued future growth. A shift towards larger and newer vessels, including more container ship traffic and LNG-carrying vessels, would change the overall profile and makeup of the range of vessels plying these waters. In particular, three port communities – Stewart, Prince Rupert, and Kitimat – are each poised for, or already undergoing, significant expansion plans. Corresponding foreshore development to accommodate growth in this sector will also impact coastal values such as commercial fishing, recreational use, and habitat value.

The drivers of this growth are largely related to the burgeoning Asian market. Asian demand for energy products and commodities, as well as import of processed goods, is expected to grow. The significance of this increase in shipping density has implications for species dependent on acoustic habitat. The water bodies of Dixon Entrance, Chatham Sound, Douglas Channel and Caamaño Sound, as well as the adjoining Hecate Strait and Queen Charlotte Sound, will all be subject to increased noise from shipping.

Drawing on data from Marine Communication and Traffic Control Services (Canadian Coast Guard), Port Authority reports, forecasts for economic development, and various project descriptions (see list of sources), an estimation of the numbers of ships, by vessel class (Figure 2) and region (Figure 3), was made for the time span 2006 – 2028. Numbers on the vertical axis refer to vessels visiting the region / year. Given the diversity of data sources, market uncertainties, and gaps in time series for some sub-sectors, these graphs indicate approximations only.

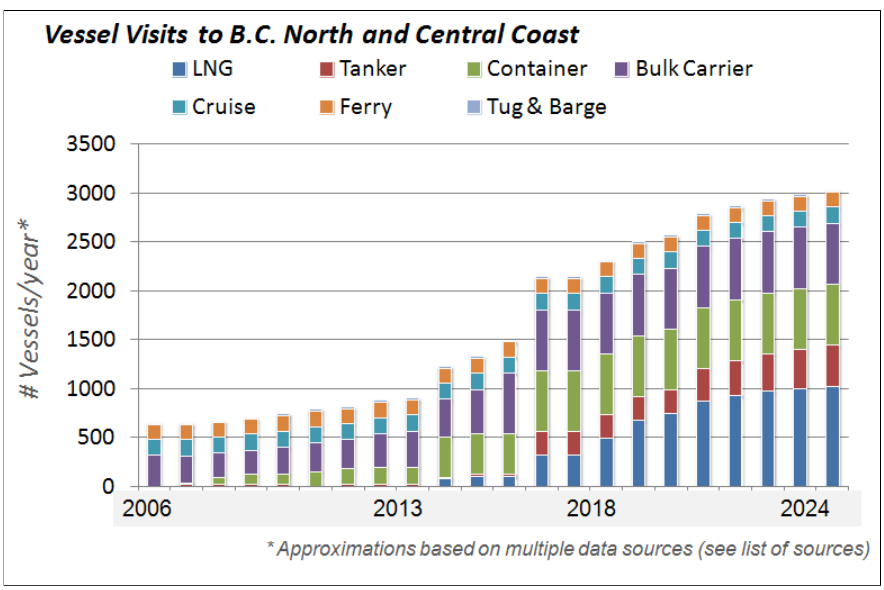

Figure 3. Actual and estimated future number of vessel visits to British Columbia's north and central coast by vessel class. Courtesy of Mike Ambach.

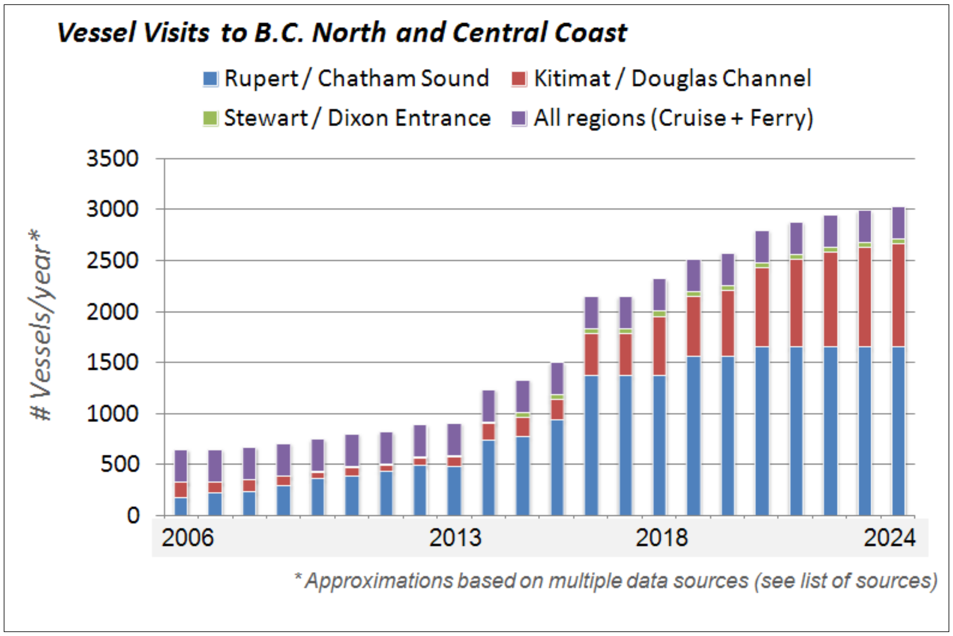

Figure 4. Number of vessel visits by area (actual and estimated future) to British Columbia's north and central coast. Courtesy of Mike Ambach.

The largest of the three port communities, Prince Rupert, is experiencing the most solid growth. The completion of a container terminal expansion is expected for 2015, with a second terminal planned for 2018. Two LNG proposals are also presently being considered in the region[1], while four other companies (Imperial Oil Resources Ltd., SK E&S, Nexen Inc., Woodside Petroleum Ltd.) have expressed an interest[2]. With 'shovels in the ground' on a number of other projects, doubling of coal exports, new potash and wood pellet export facilities, and continued grain and other raw commodities export, the gross tonnage of goods moved is expected to continue to grow into the foreseeable future.

The Port of Stewart, by far the smallest of the three ports, is nonetheless well-situated to play a role in the export of mineral products from mining developments proposed for, or currently underway, in Northwest B.C.[3] The Port of Kitimat is currently seeing significant economic activity with the upgrading of the Alcan facility, leading to an expected growth in throughput upwards of 48%. At the time of writing, three LNG export proposals are seeking regulatory approvals[4]. The proposed Enbridge Northern Gateway project for this region is still under review as well. Considering all current and future proposed projects, trends point to a near-doubling of vessel transits in the region by 2020, increasing to a tripling of vessel transits by 2030 (Figure 4).

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[1] Northwest LNG, Prince Rupert LNG.

[2] Four energy companies vie to build LNG in Prince Rupert, April 11, Business Vancouver online: [http://www.biv.com/article/20130411/BIV0108/130419978/-1/BIV/four-energy-companies-vie-to-build-lng-in-prince-rupert]

[3] Terrace Economic Development Authority website: Major Project Overview [http://www.teda.ca/files/4313/1653/1691/Major_Project_Map_May_18.pdf]

[4] Kitimat LNG, BC LNG, Canada LNG

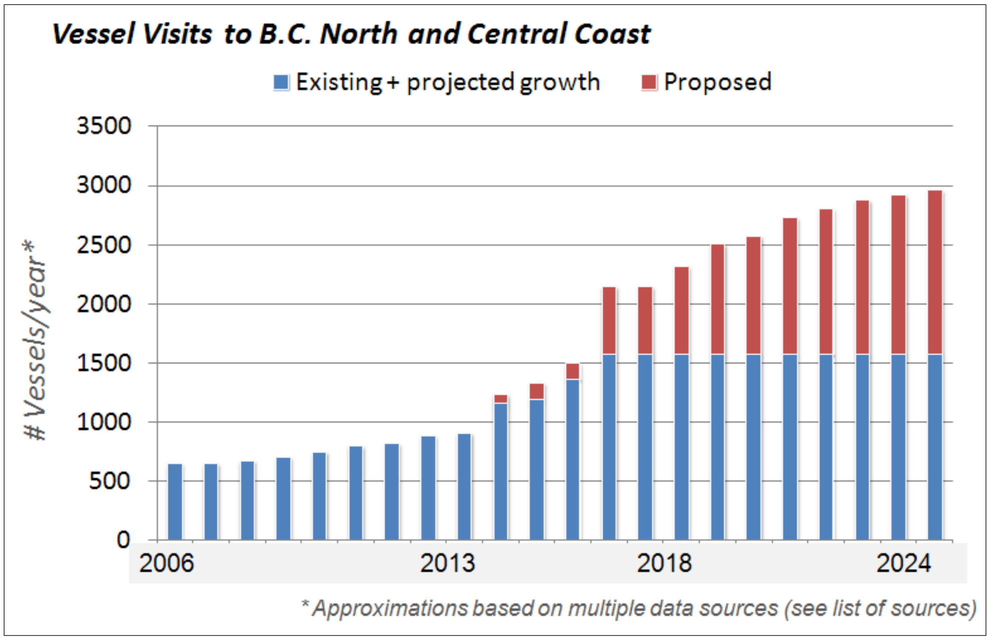

Figure 5. Total number of actual and estimated future visits to British Columbia's north and central coast. Courtesy of Mike Ambach.

Currently, the largest vessels in the region include Panamax-class and smaller Capesize-class vessels (up to 100,000 DWT approximately). Increased growth will see larger vessels, possibly in the VLCC class for heavy oil tankers upwards of 250,000 DWT) and large LNG vessels.

Notably, these estimates are for transiting commercial vessels only, and do not reflect the operational presence of tugs providing assistance to larger vessels. MCTS data shows up to 28% of all vessel traffic is comprised of local tug transits – the corresponding number for which can be expected to rise in accordance with increased large vessel traffic. As well, the above estimates do not reflect trends in smaller vessel traffic such as fishing boats, water taxis, charter operators, or pleasure crafts. Nor do they reflect the presence of military, coast guard, or research vessels. While the overall contribution from the latter toward underwater noise levels is much smaller than for larger vessels, significant issues have been raised regarding the displacement of vessel traffic, increased risk of collision, and other cross-sectoral conflicts. One can imagine a growing level of underwater noise, shifting both temporally and spatially across the range of frequencies corresponding to different vessel types.

Other potential sources of underwater noise include: noise from the construction phases of port growth, noise from seismic activities (should the current moratorium on offshore oil and gas exploration be lifted), and noise from piling operations associated with potential future offshore renewable energy projects.

Examples of vessel traffic assessment, including future trends, have been developed in neighbouring Southeast Alaska[5] and for the Aleutian Islands[6]. Given the similar geographic context and to some

[5] Nuka Research & Planning Group, LLC. (2012). Soughteat Alaska Vessel Traffic Study, July 23, 2012, Revision 1.

[6] DET NORSKE VERITAS & ERM - WEST, I. (2010). Aleutian Islands Risk Assessment Phase A – Preliminary Risk Assessment. Prepared For: National Fish and Wildlife Foundation, United States Coast Guard, Alaska Department of Environmental Conservation (pp. 1–98).

extent, the shared vessel traffic[7], it may be advisable to work towards a shared approach to future scenarios for marine vessel traffic.

A number of critical questions can be raised at this point to better inform our understanding of noise-related cumulative impacts of multiple projects in the region:

- Within the typical regulatory approval timeline, when and how does noise get identified?
- How to establish shared parameters for noise assessment among the various development proponents in the region, while accounting for seasonal variation, masking effects, and appropriate geographic range?
- How to plan around (noise) mitigation in a rapidly changing environment?
- What is essential to know about proposed/new vessel traffic now, and how can that flow of information be facilitated?

List of Sources

- MCTS data
- Prince Rupert LNG Project Description 2013
- Pacific Northwest LNG Project Description 2013
- LNG Canada Project Description 2013
- Transport Canada TERMPOL Assessment for Enbridge Northern Gateway 2012
- Shipping on the British Columbia Coast: Current Status, Projected Trends, Potential Casualties, and Our Ability to Respond: A Briefing Report 2011
- BC Shipping News
- Prince Rupert Port Authority Annual Reports
- PRPA: Shipping Trends and Future Activity on BC North Coast 2012
- Aleutian Islands Risk Assessment Study 2010
- Southeast Alaska Vessel Traffic Study 2012
- PNCIMA Atlas 2012
- BCMCA Marine Atlas of Pacific Canada 2012
- Port of Kitimat Economic Development Statistics, Major Projects briefs
- Origin, Destination & Marine Traffic Volume Survey TERMPOL Surveys and Studies 2010
- District of Kitimat Investment Summary 2013-2015
- Kitimat Modernization Project
- Stewart Bulk Terminals Expansion Project
- Northwest BC Major Projects, Terrace Economic Development Association 2011
- Adding it All Up Conference Proceedings, 2012 Bulkley Valley Research Institute
- Canada LNG Project Description
- PRPA Land Use Plan 2020
- Transportation Assessment of the Central and North Coast of British Columbia March 2, 2009

[7] Ships transiting to or from northern ports in Asia follow the great circle route through Unimak Pass and the Aleutians. This is the case for the majority of the shipping growth in Northwest BC outlined here.

The Importance of Underwater Noise Monitoring and Mitigation in Sensitive Areas: the Central Coast as a Case Study

Janie Wray, Cetacealab

Introduction

Over a decade ago my research partner Hermann and I bought a boat and travelled up the coast of BC. We were looking for a place to observe whale behaviour with little impact from people and anthropogenic noise. We found what was truly the perfect place on the south end of Gil Island. We contacted the band council of the First Nation village of Hartley Bay and asked for permission to build a research facility on their territory. They embraced the idea and the following year we built Cetacea Lab. Gil Island is extremely isolated, no roads, no power, no people and the only mode of travel is by boat. Year by year we added to the lab and our tiny network of hydrophones grew. At the same time we observed a continuous growth in the number of humpback and fin whales that were using the area. In April we began to record the calls of resident orca. We could encounter Transient (Biggs) orca at anytime of the year. In 2008 we installed a new hydrophone in Caamaño Sound and realized there was more orca activity than we first realized. In 2008 we established an out camp at the same location so we would have eyes on what was becoming a cetacean highway! On this hydrophone alone, between orca and humpback feeding calls, there were days we recorded calls from sunrise to sunset – it truly is an acoustic paradise. Whales have a unique way of hearing and seeing, but hearing in particular is highly developed, so much so that they depend on it in the same way that we depend on a combination of our eyes, ears and nose. The purpose of this presentation is to share with you what we have witnessed for the last decade in regard to how whales react to and depend on sound.

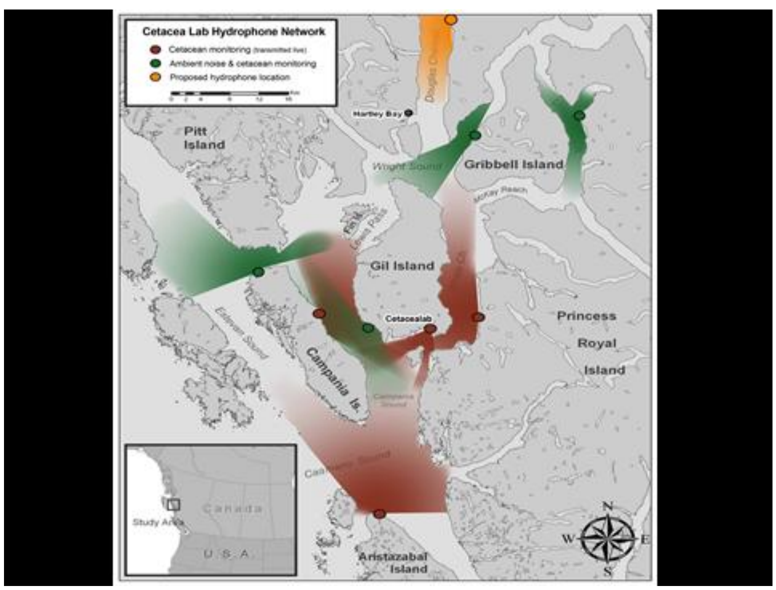

Figure 6. Acoustic monitoring by Cetacealab for fin, humpback and killer whales. Areas in red are monitored for cetaceans using hydrophones, areas in green are monitored for cetaceans and noise using calibrated hydrophones, and areas in orange are proposed locations for hydrophones. Courtesy of Cetacealab.

<u>Resident killer whales</u> live in strong family groups that will last their lifetime. This bond is formed by an acoustic dialect that is passed down from mother to calf, from generation to generation. When these

whales spread out to forage they continuously call out to each other through the dark sea to ensure all members are present. Just as we walk into a room and use visual cues to detect our companions they achieve this through sound.

Transient (Biggs') killer whales often travel in complete silence. They are listening for the sounds of their prey in order to feed themselves and family. Therefore they are dependent on a quiet ocean.

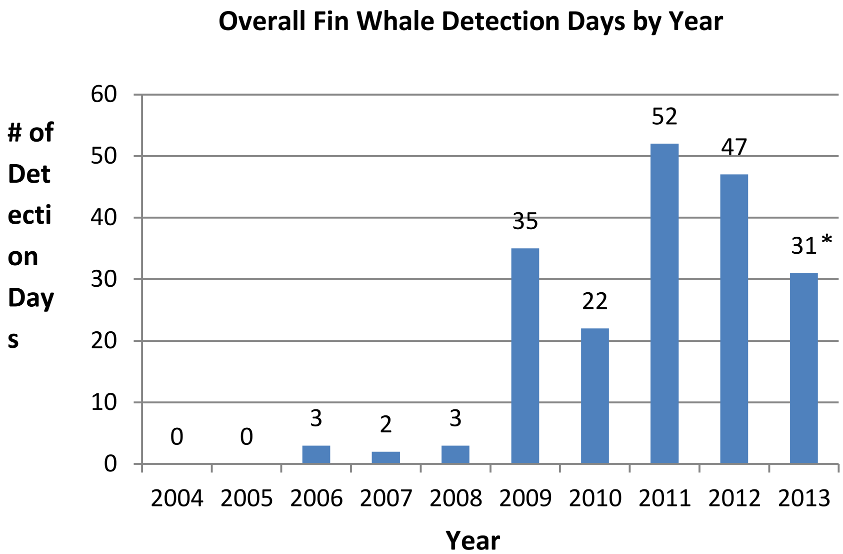

Figure 7. Number of fin whale detection days per year at Cetacealab. Fin whales are now commonly seen from land from early May to late September. Courtesy of Cetacealab. *Data for 2013 as of July 30.

Fin whales vocalize with low frequency calls, which indicate they are able to communicate with each other at great distances. Ambient noise levels would have a direct impact on this ability as well their ability to locate their prey. We spotted our first fin whale in 2006 with only a few sightings for the next couple of years. Now it is a common occurrence even from land to see these giant cetaceans starting in early May until late September (Figure 7).

Humpback whales migrate every spring from warm tropical waters to the nutrient rich waters of coastal BC. In our research area from Douglas Channel to Caamaño Sound we document the arrival of every whale with a photo ID. In 2004 and 2005 we documented 42 individual humpback whales – by the end of 2012 that number was over 300.

When humpback whales bubble net feed they use a distinct feeding call with bubbles to force a bait ball into a tighter group and towards the surface. This feeding call may also signal seals, sea lions, Dall's porpoise, and even other humpback and fin whales to the presence of food – a dinner bell of sorts. On many occasion we have observed a single humpback whale take a direct line towards these feeding calls from a great distance. There is another mammal that may also be attracted to this feeding call – the Biggs orca – knowing a variety of prey may be available in one location.

Breaching, tail slaps, and pectoral fin slaps are extremely dynamic to witness. What is most interesting though is what this sounds like underwater – it is explosive! When you witness this with a hydrophone in the water it is shocking - you will hear the sound of the breach underwater before you hear it in the air! When one whale starts to breach it is not surprising to see another one many km away also begin to breach. Sometimes a lone humpback whale will start a series of up to 50 tail slaps – again the sound is traveling for miles.

Song display – in the first few years we would only record 30 to 50 hours a season of humpback whales singing. In 2009 this number suddenly jumped to over 500 hours. Sometimes a humpback will do one call, wait for the echo to end, call again, again listening to the echo, then the whale will change the beginning or ending, then eventually it will go onto song. In these moments we feel as though the whale is actually practicing what may be the start of the new version of the song for this season. All these whales will pick up a song for the season. A great mystery is why males sing. One would think this is to attract females – instead it attracts males.

Whales may well believe they have found paradise in regard to an area they can freely communicate, feed and navigate in a quiet ocean. Today the sound we record more than any other is that of whales. The potential for this to change with an increase in anthropogenic noise from shipping vessels needs our serious attention. We are presently working on a joint project with Hartley Bay and WWF to better understand the impacts of ambient noise on cetaceans from Douglas Channel to Camaano Sound.

Surfacing fin whale. c. forwhales.org

III - TOOLS TO MANAGE NOISE: MPAs

Marine Mammal Protected Areas – Global Experiences and Ideas for Canada's Pacific with Relevance to Noise Issues

Erich Hoyt, Whale and Dolphin Conservation

Marine protected areas (MPAs) are valuable tools for cetacean conservation when they help address and manage threats to cetaceans. This value could increase if MPAs could also help reduce the ensonification of cetacean species from various loud impulse sounds, as well as from the increasing ambient noise due to human activities in the ocean. Currently, there are more than 7,000 MPAs worldwide in more than 100 countries. Of these, some 575 MPAs worldwide feature or include cetacean habitat (Hoyt, 2011). Another 165 areas have been proposed. Yet few MPAs provide explicit protection from ensonification such as ship traffic, sonar or from seismic exploration, although controls in some areas on oil and gas exploration and other activities may reduce ensonification.

In MPA management plans, specific references to noise are rare — mainly confined to the US national marine sanctuaries and The Gully in the North Atlantic, off eastern Canada. In Australia, the Great Barrier Reef Marine Park (GBRMP) Management Plan makes no mention of noise but since its establishment in 1975, it has added a specific cetacean plan (2002) + 33% highly protected areas (up from 15%). Relevant to noise considerations, the park has International Maritime Organisation (IMO) rules such as a Particularly Sensitive Sea Area (PSSA) and a pilotage system that attempts to control impacts on the area from shipping (1990). All mining and seismic activity is banned in the park unless approved for research (1999).

Petroleum exploration cannot be undertaken in many other Australian IUCN Category I and II MPAs. Still, MPA declarations have not prevented exploration permits being granted just outside the MPAs where noise would impact the MPA. Exploration is permitted in the Category VI MPAs which some MPA practitioners do not consider real MPAs because of their focus on sustainable development. Recently a Federal ministry declared that exploration was an unacceptable risk to the World Heritage Area of the Ningaloo MPA in Western Australia.

However, even with the few existing regulations reducing ensonification, are the current MPAs large enough to protect cetaceans from noise? The size of the MPA needed depends on the species sensitivity, the location (bathymetry and bottom topography) and noise source (dB, directionality, frequency). Still, we can say in general terms that some protection may be conferred if loud mid-frequency (MF) sounds of over 200 dB are excluded from areas several tens of kilometres away from critical habitats (implying an area on the order of at least 1000 km^2), while protection from loud low frequency (LF) sounds of over 200 dB might require hundreds or even thousands of kilometres distance from sound sources (implying areas on the order of a million km^2 or more).

Of the 575 MPAs with cetacean habitat, at present only 229 of these are 1000 km^2 or larger: 160 MPAs are 1000—9,999 km^2; 51 are 10,000—99,999 km^2; and only 18 MPAs are 100,000—1,000,000 km^2. Another 208 MPAs are in the category of 100 to 999 km^2 and could confer some MF protection if outer low-noise zones were added, for example, as part of a marine biosphere reserve design strategy with outer transition and buffer zones. Currently, no area can confer protection from loud LF noise unless national or international sanctuaries could be converted to reduced ensonification or low-noise zones. The 28 national EEZ sanctuaries range in size from 120,000—9 million km^2, with most on the order of 1 million km^2. National sanctuaries offer minimal cetacean protection (except from cetacean hunting) and have no specific management plans, but countries are responsible for managing resources within their EEZ.

Regarding the status of MPA protection for sensitive beaked whales, 65 MPAs (out of 570 total) in the waters of 12 countries list Cuvier's beaked whales as resident or transient, but they are not the key or most common species present or the focus of conservation activities (Hoyt, 2011). Only one MPA has a substantial size and potential protection: Pelagos Sanctuary for Mediterranean Marine Mammals. After the widely publicized Cuvier's beaked whale strandings around the Canary Islands associated with mid-frequency sonar, the Spanish Navy agreed to a 50 nautical mile (92.6 km) exclusion zone around the Islands which has worked in terms of eliminating strandings since 2007 (Fernández et al., 2013). On this basis, a map is being prepared of Cuvier's critical habitat in the Mediterranean through sightings, surveys and habitat modeling with recommended 50nm exclusion zones for military sonar (Notarbartolo di Sciara, pers. comm.). Only one species of beaked whale has dedicated habitat under explicit legal protection as an MPA: the northern bottlenose whales of the Gully.

The high seas occupy more than 50% of the surface of the ocean yet only 0.17% is in MPAs (Spalding et al., 2012). Currently, responsibility for high seas protection is divided among four treaties or conventions while a much wider remit for international protection is being sought through the United Nations. OSPAR covers the North Atlantic high seas and CCAMLR the Antarctic region, and both are in the early stages of creating MPA networks. The Convention on Migratory Species (CMS) has seven regional agreements focusing on marine mammals, all of which can recommend MPAs that then need to be implemented by the countries signing the agreement. The agreements are ACCOBAMS (for all cetaceans in the Mediterranean and Black seas and adjacent North Atlantic), ASCOBANS (for small cetaceans of the Baltic & North seas and adjacent North Atlantic), Wadden Sea Seals, cetaceans in the Pacific Islands Region, dugongs, Mediterranean Monk Seals, and West African aquatic mammals.

The Convention on Biological Diversity (CBD) has the most far-reaching mandate, covering all of the high seas, and its influence extends into national waters. The CBD process has been largely focused on identifying ecologically or biologically significant areas (EBSAs) through seven key criteria (Hoyt, 2011). Over the past two years, CBD regional workshops have gradually moved from ocean basin to ocean basin around the world, inviting species and ecosystem experts, as well as key authorities in adjacent countries, to select sites based on data and expert assessment. These are not MPAs, but represent potential MPAs as recommended through this scientific process to identify important high seas habitat. The CBD has also recently acknowledged that background chronic noise and acute noise sources are having an impact on biological diversity at sea and that efforts should be made to control noise, although specific measures have yet to be recommended.

Besides CBD, the CMS treaties in the Mediterranean-Black seas (ACCOBAMS) and the Baltic and North seas (ASCOBANS) as well as OSPAR have produced recommendations on noise mitigation as part of their mandates but awareness has yet to move to active implementation in designated MPAs.

In conclusion, planning has been slow to incorporate noise pollution concerns and needs to catch up (in terms of size issues for MPA design and zoning proposals, as well as in terms of awareness of stakeholders, management plan provisions and reviews). Is it possible to designate or create new low-noise zones surrounding existing MPAs? Further work on designing MPAs from the start using the marine biosphere reserve model with noise mitigation and reduction of ensonification, would be productive. Creating low noise areas is important for (1) precautionary conservation and sustainable business approaches — because we don't know the full extent of what our big "noise experiment" will do to the ocean's biodiversity (our biological capital) and the health of the ecosystems that support all of us; (2) education — the perception of the public that we are all aware of this issue and working to do something about it; and (3) science — to learn more by comparing highly protected quiet areas with ensonified areas to quantify measurable differences in life history outcomes or persistent welfare issues for marine mammals.

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IV- OTHER TOOLS TO MANAGE NOISE

EU Marine Strategy Framework Directive Descriptor 11: Underwater Noise

Lindy Weilgart, Dalhousie University

The European Union Marine Strategy Framework Directive (MSFD) was established in 2008 by the European Parliament and the Council of the European Union. In 2010, the European Commission set the criteria for Good Environmental Status (GES) by various Descriptors—11 in total. GES needs to be achieved in European seas by 2020. The MSFD is the first binding regulation that specifically mentions noise and is a major effort in addressing underwater noise at a large scale.

The MSFD represents an ecosystem scale of management and a regional approach to implementation. First, Member States must assess the status in their national marine waters and then establish environmental targets. Progress must be reported to the European Commission in 6-yr cycles, beginning for the first time in July 2012. Monitoring programs must be established by 2014, and an implementation of the marine strategy by 2016. While the MSFD sets the framework—structure and timeline—the details of implementation are left to the Member States. Coordination and cooperation between EU countries is key.

The MSFD does not replace existing legislation that regulates at smaller scales (SEA, EIA and Habitats Directives). There are presently no overarching EU targets but this may change. The MSFD does not apply to naval activities, but Member States should try to conduct them in line with the objectives of the Directive. Some of the GES Descriptors include maintaining biodiversity (Descriptor 1), marine food webs (Descriptor 4), and preventing contaminants (Descriptor 8). Descriptor 11 states *"the introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment."* Two indicators under this Descriptor were developed: 1) short duration--low and mid-frequency (10 Hz to 10 kHz) impulsive noise (which includes sonars); and 2) long lasting--low frequency continuous noise.

An expert group was formed (Technical Subgroup or TSG Noise) to help clarify this descriptor and give guidance to Member States. For the impulsive noise indicator, the main effect was determined to be "considerable" displacement and habitat loss by marine life. This indicator looks at the cumulative impact of activities, not individual projects. So far, most Member States have no quantitative description of GES due to insufficient knowledge of cumulative impacts.

Member States are advised to assess the pressure of pile driving, seismic surveys, and sonar cumulatively (something not achieved previously at this scale), and then evaluate the effects and set targets. They need to assess the area impacted and set up a register of impulsive noise activities at the regional and EU level so as to establish the current level and trend in impulsive sounds.

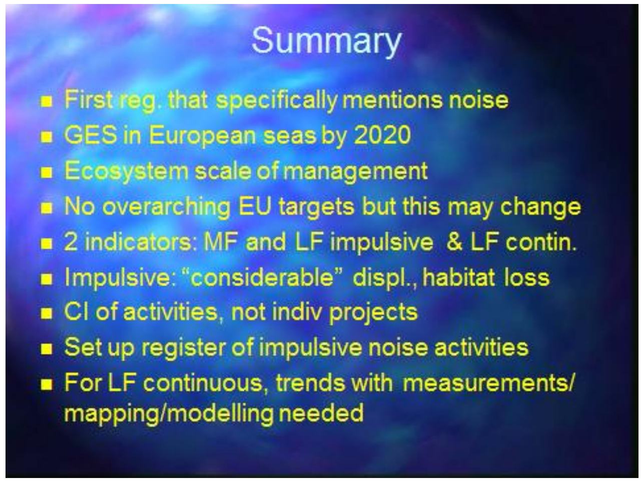

Figure 8. Summary of the EU Marine Framework Strategy Directive. Courtesy of Lindy Weilgart.

For the continuous, low-frequency noise indicator, trends in ambient noise in each of two third octave bands, one centred at 63 Hz and the other at 125 Hz*,* need to be measured or modelled (other frequencies can be added as appropriate). In 2010, thresholds were given, namely not to exceed the baseline values of the year 2012 or 100 dB re 1μPa rms; averaged in those octave bands over a year. I have since determined that this baseline or 100 dB level was suggested by an independent expert group. The EC and EU member states did not take over that suggestion. The TSG Noise suggested that trends by themselves are not sufficient to describe GES and that a combination of measurements and modelling/mapping is needed.

Ocean Noise Management: Three Lessons from the United States
Michael Jasny, Natural Resources Defense Council

The United States began regulating impacts from ocean noise in the 1980s, earlier than virtually any other country, and still has the reputation for having one of the most advanced, sophisticated approaches in the field. American entities, like the U.S. Navy and U.S.-based oil and gas corporations, spend more than $25-30 million (USD) each year on noise research; and U.S. federal wildlife agencies surely spend as much or more regulatory energy on ocean noise than their counterparts anywhere on the planet, and are responsible for some of the major advances in impact analysis. But in some respects the rapid advances made in the late 1990s and early 2000s have hindered progress in the 2010s, with U.S. regulatory agencies slow to advance their environmental analysis and management policy in step with the best available science. The substantial influence that the United States holds worldwide in this field makes it all the more important to identify where it lags behind, and where it is now gradually pushing forward. To this end, I organized my presentation as “three lessons” that Canada can draw from its southern neighbour.

(1) *Be honest in estimating take.*— In the 1990s, the National Marine Fisheries Service (NMFS), which exercises jurisdictional authority in the United States over most marine mammal species, developed a simple three-tier scheme for determining whether animals were affected, or “taken,” by human noise. Marine mammals exposed to “continuous” levels of noise of 120 decibels, or “intermittent” noise of 160 decibels, were considered to have had an adverse behavioural response; animals exposed to noise above 180 decibels were considered “injured.” Except for military sonar, for which separate thresholds have been set, these numbers have lingered to this day as received wisdom, imposed by the agency in dozens of environmental reviews each year and borrowed by other jurisdictions for their own analysis.

It is important to appreciate, however, that marine mammal “take” is both a biological and a legal concept, deriving as it does from the U.S. Marine Mammal Protection Act, 16 U.S.C. § 1362(18). On the one hand, scientific developments have challenged NMFS’ thresholds. For example, the hoary 160 decibel threshold has been criticized by leading bioacousticans as “overly simplified, scientifically outdated, and artificially rigid” (Clark et al., 2012), and fails to account for intraspecific variability (as dose-response curves purport to do), for particularly sensitive species (as analysis of Navy exercises do for harbour porpoises and beaked whales), for negative bias in the observation of marine mammal impacts (based as it is on a series of 1980s studies with limited observational capacity), or for masking effects (which require a different analytical methodology altogether). These several failings mean that the threshold, aside from being outdated, is insufficiently conservative in its approach.

On the other hand, an institutional imperative lies upon the agency to keep its “take” numbers reasonably low. The Marine Mammal Protection Act sets a number of qualitative ceilings on the amount of “take” that NMFS can legally authorize, one of which, a limitation on take to “small numbers of marine mammals,” is directly tied to the agency’s take estimates. The countervailing pressure has thus far stymied inclinations within the agency to fully acknowledge and account for low-level, sub-lethal harm—a recognition that is essential to any serious consideration of cumulative impacts—and has kept the behavioural impact thresholds frozen in time (although the agency is presently making another attempt to revise them). Canadian regulators and managers should not follow NMFS into this cul-de-sac, but instead recognize that U.S. thresholds do not represent the floor of sub-lethal effects.

(2) *Think cumulatively.*— Here again, for cumulative impacts as for take thresholds, the agency’s interpretation of the Marine Mammal Protection Act has hindered progress. Most noise-producing

activities are subject to the Act's general authorization provisions, which are triggered "upon request" by project proponents within specified geographic regions. As NMFS interprets this language, it is the project proponent who decides the scope of authorization, and the proponent can group his activities together or segment them into smaller units. Various user groups have taken advantage of the agency's liberality by dividing their activities into smaller segments, effectively avoiding cumulative impact review under the statute. The Apache Alaska Corporation, in what is perhaps the most egregious of recent examples, split a three- to five-year airgun exploration survey—taking place mostly within the critical habitat of an endangered and declining beluga whale population—into a sequence of less legally objectionable single-year surveys. Nonetheless, NMFS encourages user groups, particularly other federal agencies such as the U.S. Navy and Bureau of Ocean Energy Management, to undertake programmatic regional reviews and, over the next few years, is attempting itself to develop comprehensive, multi-sector noise management policy.

For cumulative impacts, the much-desired holy grail is a comprehensive, quantitative model, such as the Population Consequences of Acoustic Disturbance model originally proposed by a National Research Council panel in 2005. That model begins with acoustic output and runs through a series of transfer functions to effects on individual vital rates and, ultimately, to populations. The Office of Naval Research has led a multi-year project to realize the model, using a handful of well-studied marine mammal populations as the basis of its pilot studies; but producing an operative model is the work of decades, at best. In the meantime, proxies are needed for adverse population-level impacts. For most U.S. cetacean populations, as Taylor et al. (2007) observed, there is a high probability that even a precipitous population decline (50% over fifteen years) would go undetected given present efforts; and the literature (e.g., Goldhagen et al., 2013; Hatch et al., 2012; Miller et al., 2009; Moore and Barlow, 2013) increasingly justifies concern that noise is negatively affecting marine mammals at the population or species level.

Regulators and managers should establish conservative proxies for population impacts. Such proxies may be based, for example, on the percentage of a population exposed to certain levels of noise, as was the case of the Environmental Impact Report prepared on the Central Coastal California Seismic Imaging Project (Wood et al., 2012). Or they may be based on existing baselines of exposure, on the assumption that current levels of acoustic exposure are harmful and should be reduced over time. One leading example of this approach is the 2008 Hamburg Statement, which called for a gradual reduction of global ambient noise energy in the 10-300 Hz band relative to current levels (Wright ed., 2008). Additionally, regulators and managers should require, over the life of major projects, monitoring with a significant capacity to detect abundance trends in vulnerable populations.

(3) *Evolve beyond the near field.*—For most jurisdictions, the common denominator in noise mitigation is the use of a "safety zone," which requires powering or shutting down a powerful sound source if marine mammals are detected within a short distance. The U.S. helped pioneer the safety zone in the 1980s and 1990s, initially in reducing injury risk from seismic airgun exploration in the Arctic and off the California coast, then in addressing risk from naval training, pile driving, and other activities. Today the majority of management energy is spent on designing protocols for safety zone maintenance and ramp-up. This is true even though the impact radius around most powerful sources vastly exceeds the narrow band of waterspace that safety zones and ramp-up are designed to protect (e.g., Fleishman and Streever, 2012).

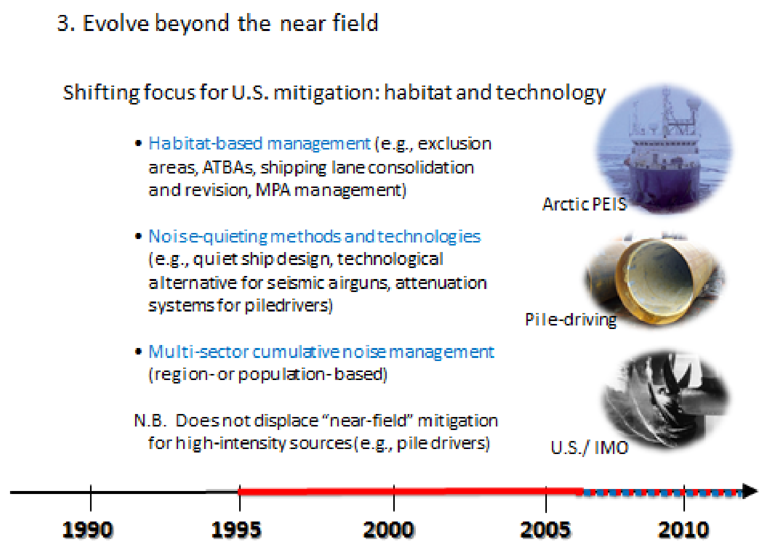

Figure 9. One of three lessons learned from the US experience- move beyond safety zones. Mitigation should be habitat based, use best available methods and technologies for noise reduction, and use a multi-sectoral approach to management. Courtesy of Michael Jasny.

Nonetheless, the U.S. has begun to focus attention on mitigation that addresses the full environmental footprint of the noise source. Specifically, these measures include habitat-based management, such as time-area closures (e.g., for seismic exploration in the Beaufort and Chukchi Seas), shipping lane consolidation and rerouting (e.g., in the approaches to the Ports of Oakland and San Francisco), and protected area management (e.g., in the National Marine Sanctuaries); noise-quieting methods and technologies, such as quiet-ship design (which effort the U.S. is leading at the International Maritime Organization), technological alternatives to seismic airguns, and noise reduction and attenuation systems for pile-driving; and, though at the very early stages of development, multi-sector cumulative noise management (for which NOAA's recent initiative to map noise levels and cetacean distribution across the U.S. Exclusive Economic Zone is the first step). Regulators and managers in B.C. should likewise develop managerial tools for noise that reflect the scale of the problem, and are not limited to protecting animals from direct injury close to a sound source.

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Northern Gateway Marine Mammal Protection Plan
Andrea Ahrens, Stantec

Northern Gateway is committed to minimizing or eliminating adverse environmental effects of the Northern Gateway Pipelines Project on the marine environment. To reduce the likelihood and extent of adverse effects of underwater noise on marine mammals (i.e., from construction of the marine terminal and routine marine transportation operations), Northern Gateway will implement a variety of best industry practices and mitigation measures. While the same type of effects to marine mammals are created by other large vessels in British Columbia today, no other operator or future operator has yet adopted similar mitigation measures.

Northern Gateway is proposing to build twin pipelines to transport diluted bitumen and condensate between Bruderheim, Alberta and Kitimat, British Columbia, as well as a two-berth marine terminal in Kitimat that will receive an estimated 220 tanker calls per year. Northern Gateway recognizes that increased marine transportation activities associated with the Project will increase the amount of underwater noise produced in the confined channels between Kitimat Arm and Hecate Strait (i.e., the Confined Channel Assessment Area [CCAA]). Potential effects on marine mammals associated with underwater noise include temporary habitat avoidance, reduced feeding efficiency, behavioural change, increased stress, and communication masking. Sound levels capable of causing temporary or permanent auditory damages (i.e., ≥180dB re: 1µPa) were not predicted by modelling of marine transportation activities.

Northern Gateway has committed to a suite of mitigation measures to reduce the potential effects of underwater noise on marine mammals associated with the Project. Commitments related to marine mammals, including mitigation, monitoring programs, and research initiatives, have been compiled in Northern Gateway's Framework for the Marine Mammal Protection Plan (MMPP). The Joint Review Panel has included fulfilment of the MMPP as an anticipated condition of regulatory approval of the Project should it proceed.

The purpose of the MMPP is to outline measures that Northern Gateway will implement to manage and monitor Project-related environmental effects on marine mammals associated with underwater noise, blasting, and other potential marine mammal-vessel interactions. The MMPP is currently filed as a framework document. This comprehensive plan will be further developed and modified through an engagement process that will include Fisheries and Oceans Canada (DFO), participating Aboriginal organizations, and external research organizations and experts. Data collected through the MMPP would be used as part of an adaptive management program to identify any required changes in Project operations and/or environmental management approaches and on-going monitoring strategies. As such, the MMPP will be a living document that may go through multiple iterations over the life of the Project.

Northern Gateway considered three stages for which to consider potential mitigations for acoustic effects: (i) noise reduction at the source, during the design stage; (ii) reduction of noise produced by vessels during operations; and (iii) reduction of noise through adaptive management and research during the follow-up and monitoring stage.
For the design stage, Northern Gateway has committed to incorporating best commercially-available technology at the time of the design and construction of purpose-built tugs (primarily in engine vibration reduction and propeller design), so that escort and harbour tugs produce the least underwater noise possible.

At the operations stage, Northern Gateway has committed to reducing the underwater noise output of Project-related vessels though the use of mandatory speed restrictions in the CCAA, “core humpback whale area”, and “CCAA approaches”. Currently available information on the seasonal distribution of humpback whales in the CCAA suggests that this species occurs in greater numbers in Wright Sound, Squally Channel, Campania Sound and Caamaño Sound from May to November. For the purpose of the assessment, these areas were referred to collectively as the core humpback whale area. The CCAA approaches refer to areas within Hecate Strait, in close proximity to the CCAA (i.e., around Browning Entrance and west of Caamaño Sound) within which additional seasonal speed restrictions may apply. The spatial and temporal boundary of these two areas will be refined through data collected by six years of marine mammal density surveys and a quantitative vessel strike analysis.

Vessel-based underwater sound typically increases with speed; the greater the vessel speed, the greater the propeller cavitation noise. Consequently, Northern Gateway has set a maximum year-round speed restriction for all Project-related tankers of 10 to 12 knots within the CCAA. While transiting the “core humpback whale area” during 1 May to 1 November, tankers and tugs will travel at maximum speeds of 8 to 10 knots, unless otherwise required for safe navigation. In the “CCAA approaches”, Northern Gateway will require tanker speeds to be less than 14 knots for the period 1 May to 1 November. Other large vessels in the CCAA currently travel at speeds of 16 to 21 knots. Surveying of seasonal whale densities and distributions will again be used to better define this period, and the quantitative vessel strike analysis will be used to better define the geographical extent of these areas.

Acoustic modelling conducted for the Project predicted that reducing vessel speed from 15 knots (a common speed for transiting tankers) down to 9.6 knots (as a result of Northern Gateway’s mitigations) would reduce sound input into the environment by nearly 12 dB. To understand what a reduction by 12 dB means, decreasing sound levels by 10 dB reduces the distance that sound extends by a factor of approximately three, and (at least in terms of human hearing) would be perceived as a sound that is half as loud. Therefore, Northern Gateway’s commitment to reduce vessel speeds means that the zone of influence for Project-related vessel noise in the CCAA is predicted to be 2-3 times smaller than in the absence of mitigations, or in comparison to many of the large ships operating in the region now.

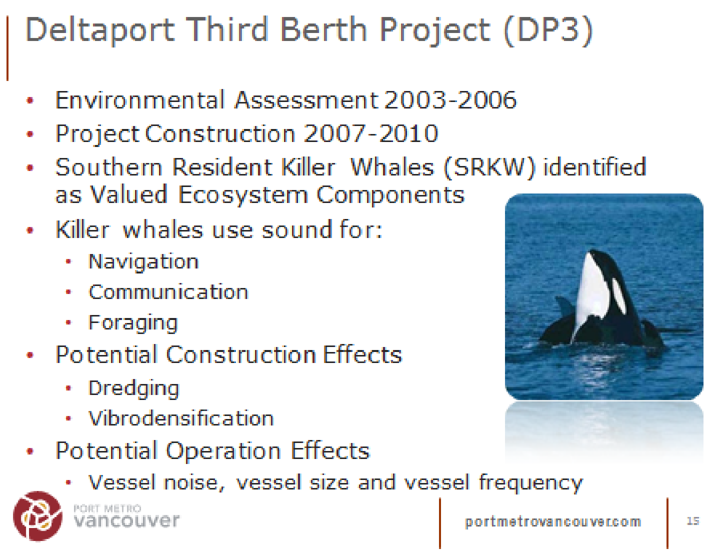
Finally, Northern Gateway has committed to a long-term marine research and monitoring program. This program will include conducting a four-year passive acoustic monitoring study, and undertaking a cooperative research initiative to address and adaptively manage important data gaps and identify options for monitoring and reducing underwater sound levels throughout the CCAA. Northern Gateway encourages a cooperative regional approach to developing mitigation measures for limiting the effects of all vessels on marine mammals.

The potential effects of underwater noise associated with vessel traffic are not unique to Northern Gateway; however, the approach that Northern Gateway is taking to minimize effects of routine operations on marine mammals is unique in the shipping industry in British Columbia and many areas in Canada and the United States. Northern Gateway believes that if other shippers and passenger liners in British Columbia waters were to adopt similar types of measures, the marine environment would actually see some net benefits in terms of reduced noise levels. Northern Gateway has committed to minimizing their incremental contribution, and it is their hope that these mitigation measures will serve as an industry example.

Lessons Learned from Port of Metro Vancouver Operations and Development and Application of Incentive Programs

Darrell Desjardin, Port of Metro Vancouver

An extended abstract was not received for this talk. It is summarised in the presentation slides below.




ECOACTION INCENTIVE PROGRAM
Since 2006 the Port Metro Vancouver EcoAction Program offers discounted harbour due rates to ships that have implemented emissions reduction measures.
Blue Circle Award Recognizes leading shipping lines participating in the program.
Silver
SAVE
35%
Gold
SAVE
47%
Bronze
SAVE
23%
EcoAction Award Levels
bluecircle
AWARD
PORT METRO
vancouver

Mechanisms for Managing Underwater Noise Impacts Under the Species at Risk Act (SARA): Critical Habitat Protection Measures

Sheila J. Thornton, Fisheries and Oceans Canada

Species at Risk Act (SARA)

The *Species at Risk Act* was passed on December 12, 2002 and came fully into force on June 1, 2004. It is designed to meet one of Canada's key commitments under the International Convention on Biological Diversity. The purpose of SARA is to prevent wildlife species from becoming extinct or extirpated; to assist in the recovery of extirpated, endangered or threatened species; and ensure that species of special concern do not become endangered or threatened.

Species are assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent organization that offers the government advice based on the best available biological information, including scientific knowledge, community knowledge and Aboriginal traditional knowledge. After receiving the assessment from COSEWIC, the government consults with concerned ministers, relevant wildlife management boards and the public on the listing decision information, which may include threats to recovery, current and proposed management measures, and possible social and economic implications of listing the species. The government then decides whether to add the species to the list of Wildlife Species at Risk (Schedule 1 of the Act). Once a species is listed, the provisions under SARA apply to protect and recover species. The list will continually evolve as species are added or removed or their status changes. The Act includes "subspecies, varieties or geographically or genetically distinct population" in its definition of wildlife species, and recognises that conservation of biological diversity may require protection below the species level.

SARA contains prohibitions against the killing, harming, harassing, capturing, taking, possessing, collecting, buying, selling or trading of individuals of endangered, threatened and extirpated species listed in Schedule 1 of the Act. In addition, SARA also prohibits damage or destruction of the residence of one or more individuals of an endangered or threatened species, as well as destruction of any part of the critical habitat of any listed endangered or listed threatened species.

Identifying Critical Habitat

SARA recognises that the protection of habitat of species at risk is a fundamental tenet of conservation. Critical habitat is defined as "the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species".

For species listed as threatened, endangered or extirpated, SARA requires the development of a recovery strategy, followed by one or more action plans based on the recovery strategy. The best available information on habitat, including the information provided by COSEWIC, is considered by the Fisheries and Oceans Canada (DFO) Recovery Team for inclusion in the critical habitat description of a species' draft recovery strategy or action plan. To assist in collating this information, DFO may develop advice on important habitat for the species in the form of a DFO Research Document. These documents are peer-reviewed and then published on the Canadian Science Advisory Secretariat website.

The recovery document development process includes two consultation opportunities during which the public can provide input: regional consultations on the draft recovery document, and a 60-day National consultation period on the proposed recovery document.

Critical Habitat - Northern and Southern Resident Killer Whales in Canada
In 2008, the *Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada* was finalized and posted on the Species at Risk Public Registry. This document identified areas of critical habitat for both populations. Once critical habitat is identified by the Minister, no person shall destroy any part of the critical habitat, and the Minister must describe in the public registry how the critical habitat is legally protected. In 2009, the Minister issued a protection order for critical habitat.

In December 2010, a Federal Court ruling regarding Resident Killer Whales and critical habitat protection (David Suzuki Foundation v. Canada, 2010) determined that the Minister of Fisheries and Oceans erred in law in determining that the critical habitat of the Resident Killer Whales was already legally protected by existing laws of Canada; and the Ministers acted unlawfully in limiting the application and scope of the protection order. To assist with the critical habitat identification process, DFO has drafted *Operational Guidelines for the Identification of Critical Habitat for Aquatic Species at Risk*, which provides standards and approaches for identifying critical habitat in a manner that facilitates the Department's legal, ecological and administrative obligations.

Critical Habitat - description
A general description of critical habitat is provided in a recovery document, and includes a clear statement referencing a defined geographic area located on a map and a summary of the area's **functions, features and attributes** (Figure 10). If applicable, the description includes an identification of additional required critical habitat, and a rationale explaining why information is inadequate to complete the critical habitat identification (e.g., what information on the species and/or the species' habitat requirements is lacking).

Fisheries and Oceans Canada | Pêches et Océans Canada

Mock Whale FFA Table

FUNCTION	FEATURE	ATTRIBUTE
Feeding and foraging	Prey availability	Species x at concentration y at location z
Feeding and foraging Resting and socializing	Acoustic environment	Received chronic sound levels TBD (SoS) Received levels of acute acoustic noise below 160 dB re 1 µPa
Feeding and foraging Resting and socializing	Physical space	A 100m radius of unimpeded physical space around a whale A 400m area of unimpeded physical space in the path of a traveling whale
Feeding and foraging Resting and socializing	Water and Air	Water and air quality of a sufficient level so as not to cause adverse health effects (SoS)

15

Canada

Figure 10. A mock Functions, Features and Attributes table. It is used to describe critical habitat for SARA-listed species. For aquatic species, the acoustic environment can be a feature of critical habitat. Figure courtesy of Sheila Thornton.

The acoustic environment can be a **feature** of critical habitat. If information is available, the acoustic environment should be identified based on its attribute(s) or a desired state of environmental quality (e.g., decibel level, frequency) in which the **function** (e.g., vocalization for mating or foraging) can be undertaken and access to the critical habitat is maintained.

Destruction of Critical Habitat

The concept of what may constitute destruction is provided in the Government of Canada's draft Species at Risk Act Policies: Overarching Policy Framework (2009): "Destruction is determined on a case by case basis. Destruction would result if part of the critical habitat were degraded, either permanently or temporarily, such that it would not serve its function when needed by the species. Destruction may result from a single or multiple activities at one point in time or from the cumulative effects of one or more activities over time. When critical habitat is identified in a recovery strategy or an action plan, examples of activities that are likely to result in its destruction will be provided."

Activities Likely to Result in Destruction of Critical Habitat (ALTD CH)

When critical habitat has been identified in a recovery strategy or action plan, the provision of examples of ALTD CH is a legal requirement of SARA. The intent of this exercise is to communicate to proponents the level of risk that their activities pose to critical habitat, identify gaps in the regulatory framework where best management practices or more effective protection is required and to provide proponents an opportunity to work with the Department to mitigate the identified risk. This should consist of specific examples of human activities (ideally taken from the Threats section of the recovery strategy) likely to result in the destruction of critical habitat. These will be the high-risk, population-level impacts that occur as a result of anthropogenic activities in or around critical habitat. In this case, the term "likely" refers to frequency of a current planned activity or an activity that has happened repeatedly in the past.

Conclusion

For aquatic species, the acoustic environment may be identified as an important feature of the habitat necessary for the survival and recovery of the species. Critical habitat for the Northern and Southern Resident Killer Whales has been identified, and includes "the lack of acoustic disturbance which would prevent the area from being used by the species for foraging, socializing, mating, resting, and in the case of the Northern Residents, beach rubbing" in its description.

To strengthen the use of SARA for protection of critical habitat, further refinement of the acoustic environment and conditions resulting in acoustic disturbance is recommended.

References

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DAY 2 – 7 JUNE 2013

V - CUMULATIVE IMPACTS AND MITIGATION/ COMPENSATION FRAMEWORKS

Ecological Risk Assessment Framework for Pacific Canada

Cathryn Clarke Murray, WWF Canada; Megan Mach, Rebecca Martone, Center for Ocean Solutions; and Miriam O, Institute of Ocean Sciences

Cumulative Effects

Cumulative effects result from the incremental, accumulating, and/or interacting impacts of an activity when added to other past or present impacts (Hegmann et al., 1999). We have classified cumulative effects into three types; 1) multiple activities sum to produce a larger magnitude stressor. For example, shipping, recreational boating and coastal construction activities all produce some degree of noise, which together result in greater underwater noise. 2) A single activity produces multiple stressors; for example cruise ships produce noise, chemical contaminants, nutrient waste and garbage, and 3) multiple activities produce multiple stressors whose cumulative effects are difficult to predict and measure (Figure 11). There can be considerable uncertainty in a single impact pathway from activity to stressor to species response but when you have multiple pathways, it is difficult to assess impact and the effect on species and ecosystems.

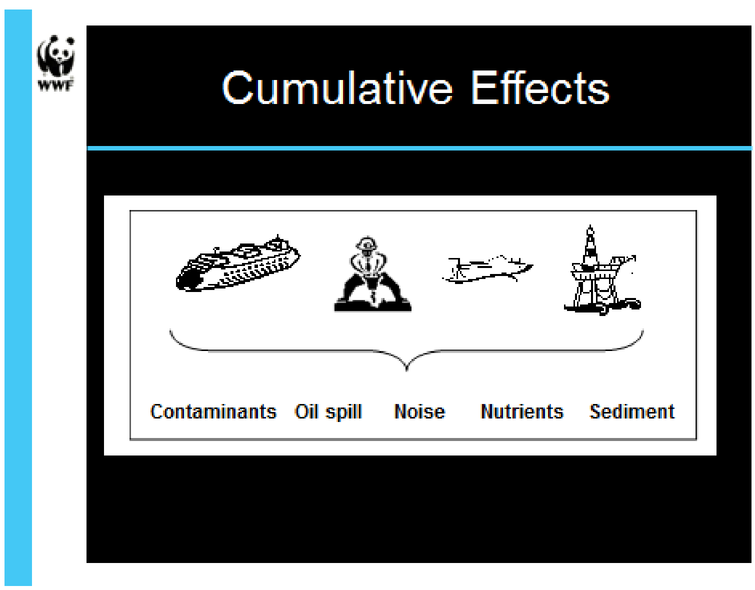

Figure 11. Multiple activities produce multiple stressors. Courtesy of Cathryn Murray.

Risk Assessment

Risk assessment is a decision making tool and ecological risk assessment uses a scientific understanding of how human activities put species, habitats and communities at risk. Risk assessment can be used for a number of purposes. Objectives can include 1) assess cumulative risk to species, for the *Species at Risk Act* or other purposes, 2) identify high risk activities, for example, risk from shipping and 3) identify high risk areas, for marine spatial planning, reserve design or ecosystem-based management. There are a number of risk assessment frameworks recently developed for marine systems (Park et al., 2010;

Hobday et al., 2011; Lawson & Lesage 2012). Here we describe a framework developed by DFO for the Pacific North Coast Integrated Management Area (PNCIMA) by Miriam O and colleagues (2012).

PNCIMA Framework

Risk assessment is based on the relationship between risk, exposure and consequence. Here we use the equation Risk = Exposure x Consequence. In the PNCIMA ecological risk assessment framework, there are three levels of risk assessment: Level 1- Qualitative, Level 2 - Semi-quantitative and Level 3 – Quantitative. Under Level 1, Qualitative risk assessment exposure and consequence are assessed on a qualitative scoring rubric. Exposure is assessed on three sub-components: Spatial (1-3), Temporal (1-4) and Intensity (1-3) and Consequence is assessed on a single component on a scale of 1-6. The recently completed pilot risk assessment for PNCIMA was completed using the Level 1 methodology. Level 2 Semi-quantitative risk assessment uses values such as percentage overlap of a species with a stressor for spatial sub-component or number of aquaculture farms per square kilometre for the Intensity sub-component. Consequence is divided into three subcomponents: Acute change, Chronic change and Recovery. Level 2 risk assessments are currently being piloted for two MPAs, Bowie Seamount and Endeavour Hydrothermal Vents. Level 3 was not discussed in detail and is not currently being employed in the Pacific region.

Cumulative risk is assessed by calculating risk assessment scores for each stressor from each activity and then the scores are added together. As an example, Samhouri and Levin (2012) recently performed risk assessment for the Puget Sound area for seven species, three types of coastal activities and five regions. Thus risk assessment can be a useful tool for assessing cumulative effects but there are still a number of uncertainties to be addressed. The acceptable threshold of risk is both an ecological and a societal question that needs to be addressed. There is need for more research on appropriate baselines for examining changes in risk and in identifying and monitoring the indicators of change.

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Transient (Biggs') killer whales listen for the sounds of their marine mammal prey.
c. forwhales.org

Framework to Incorporate and Quantify Risks of Impacts on Marine Mammal Populations from Shipping Noise, with an Arctic Case Study, Plus the Role of the CSAS Process
Jack Lawson, Department of Fisheries and Oceans

Marine Development Projects (MDP) have increased dramatically in number and size in Canada and this trend is expected to continue or be exacerbated. Assessment of MDP impacts are usually made on a case-by-case basis, without a context of effective thresholds relating them to species or ecosystem productivity, and without consideration of cumulative impacts. There is currently no national approach as to how impacts of MDP should be evaluated by DFO Science, which leads to a perception of inconsistency. This presentation described DFO's current efforts to develop a national approach to impact assessment, as well as threshold setting, monitoring standards, and development of guidelines for industry that outline minimum information needs for adequate impact assessment.

Environmental impact assessments often don't quantify impact levels using activity and risk exposures, but instead employ *a posteriori* verification to determine whether a given threshold for population decline is exceeded during the life of a project. Usually, thresholds are set arbitrarily and not treated as additive by proponents. For almost all marine mammal species threshold decline values are so small it would be difficult to determine whether they have been exceeded, even using best study designs. Worse, if such changes are detected, it may be when project activities have resulted in dramatic population declines – this is not a precautionary approach.

DFO's new framework will include thresholds for assessing impacts against population productivity in the context of population sustainability, and extended to assess cumulative impacts. I detailed the genesis of this initiative by describing an approach DFO Science applied during the 2012 review of the Baffinland Iron Mine project in the Arctic. Potential effects of noise exposure and ship strike were estimated using an input matrix approach that scales impacts by individual effects, density, and distribution for local whale and seal populations to population-level effects (Figure 12).

Over the next two years DFO and partners will improve this approach by including uncertainty in input parameters, and by incorporating more complex impacts from multiple activities, and for multiple ecosystem components. Ultimately, DFO plans to develop an "assessment tool" which will facilitate major marine project assessment for both proponents and regulators. As well, I placed this new framework within the context of the varying roles of the Canadian Science Advisory Secretariat.

(Based partly on Lawson, J.W. and V. Lesage. 2013. A draft framework to quantify and cumulate risks of impacts from large development projects for marine mammal populations: A case study using shipping associated with the Mary River Iron Mine project. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/154 iv + 22 p.)

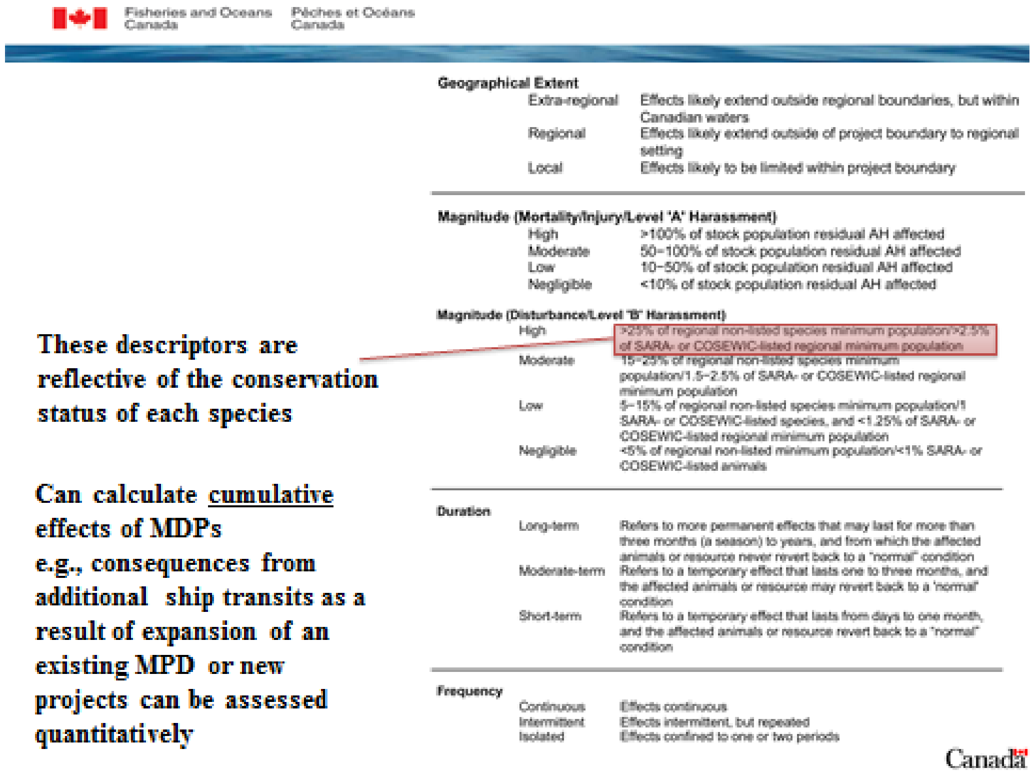

Figure 12. In the proposed framework, the severity of effects is rated according to four intensity components: the geographical extent of effects, as well as their magnitude, duration, and frequency. Courtesy of Jack Lawson.

A Compensation and Mitigation Strategy for Minimizing Noise Impacts from Increased Shipping
Lance G. Barrett-Lennard, University of British Columbia

Assessing the impact of anthropogenic underwater noise on marine life is challenging for the following reasons: sound carries great distances in water so the number and variety of organisms potentially affected by each noise emission is extensive, the sensitivity of most aquatic organisms to noise is unknown and the range of possible impacts broad, the relationship between source and received sound pressure levels varies with depth, temperature, salinity, and stratification, behavioural reactions to sound are context-specific and difficult to interpret, temporary and permanent hearing threshold shifts are hard to measure in free-living organisms, and anthropogenic noise varies widely in bandwidth, frequency distribution of energy, rise time, duration, and the consistency of those characteristics, all of which may affect its impact on aquatic organisms. Many marine animals use sound for long- and/or short-distance communication, orientation and navigation, finding prey, or detecting predators. All of these activities are impaired to some extent by noise. Even when impairment of echolocation and communication ability can be estimated, great uncertainty in the consequences of the impairment remain. In the case of echolocation, some individuals at some times may switch to hunting and navigating visually, at other times this switch may not be possible. In the case of communication, noise may impair group cohesion; reduce mating opportunities and cause displacement and/or loss of territories.

One approach to assessing noise impacts is to construct energetic models to estimate the population consequences of acoustic disturbance (PCAD). PCAD models estimate the energetic implications of noise masking (the amount of additional foraging required to survive in a noisy environment, for example) and impacts of increased energetic expenditures on survival. PCAD models are useful heuristic tools for conceptualizing and compartmentalizing noise impacts, but the difficulty of realistically parameterizing such models--due to the factors previously listed--limits their ability to generate management prescriptions.

The conundrum that environmental managers face is that while noise clearly degrades the quality of aquatic environments for vast numbers of organisms, the extent of that degradation is difficult or impossible to quantify with our current state of knowledge. The problem is similar in some ways to that faced by managers who must rule on whether proposed developments that would physically destroy a habitat area poses a significant threat to that category of habitats, and on whether at-risk or economically valuable species within or near it would be negatively affected. Because achieving high levels of certainty in these cases can be difficult and expensive, a common work-around solution is to require that developers restore a habitat that was destroyed or damaged previously to compensate for the area they propose to damage or destroy. The attractiveness of compensation as a solution in these cases is that it is a) simple in concept and practice , b) scalable (restoration areas can be larger or more complex than those subject to destruction to reduce uncertainty in equivalency), and c) precautionary. Additionally, it is possible—and common practice—to require restoration of rarer or more valued ecosystems than the one damaged to maximize environmental benefit (McKenny and Kiesecker, 2010).

Here, I propose that a compensatory framework be applied in cases where increases in shipping or other activity have the potential to increase underwater noise above a baseline of existing anthropogenic noise (Figure 13). In this framework, proponents of developments that would introduce new sources of underwater noise would compensate by reducing noise levels produced by existing sources, such that the total exposure of marine organisms to noise after the development would be no more--and preferably less--than that prior to the development. The reason that this is not only possible but in many cases practical is that most ships, and other equipment used in water, were designed and built with little if any consideration to underwater noise. In many cases they can be quieted significantly by undergoing routine maintenance (Renilson, 2009). If only those particularly loud vessels were quieted or replaced with quieter vessels, the impact on overall noise from shipping would be substantial. In addition to reducing the noise from existing sources, project proponents would naturally be expected to commit to using effective mitigation measures to minimize noise from their own activities.

For an example of how this mitigation and compensation approach might work in practice, consider the case of a commercial port proposing to add new terminals. The new terminal would allow the port to service more vessels per unit time, and this increase in shipping would be expected to increase the total production of anthropogenic noise both in the port and in its approaches. If this noise is of particular concern, perhaps because the approaches pass through a marine life sanctuary or the port or approaches are habitat for endangered species, the environmental assessment for the expansion would normally attempt to assess the extent of the harmful effect of the noise increase. According to this proposal, however, the port would commit to ensuring that ships using its existing facility reduce their noise output to compensate—or overcompensate—for the sound produced by new vessels attracted to the facility. New vessels built specifically for the new terminal would be designed to operate as quietly as practically possible. Reducing noise produced by ships using the pre-existing facility could be accomplished in a variety of ways. Incentives such as reduced berthage fees or priority access to loading/unloading facilities could be used to reward the operators of quiet ships, fees could be levied on vessels exceeding set noise thresholds, and, because noise increases with vessel speed, speed limits could be established.

Figure 13. A proposal for a compensatory framework for projects that have the potential to increase underwater noise. Courtesy of Lance Barrett-Lennard.

Despite its conceptual simplicity, this compensation and mitigation approach would not come without cost. Critical qualities of harmful noise would need to be agreed on, measurement standards for those qualities established, baseline noise prior to development determined, and a monitoring and auditing scheme established and maintained for the life of the development. In the example given above, requirements that vessels meet noise standards might affect the competitiveness of the port. Industry associations and programs by which competitors agree to meet common environmental standards might help address this issue, and public relations advantages resulting from the greening of operations might also help offset costs.

In conclusion the compensation and mitigation approach outlined above could help halt or reverse the current trend of ever-increasing underwater noise levels and, because it requires no new scientific information about the harmful effects of noise, could be implemented immediately. Because it depends on staying within or reducing existing noise baselines, however, it is not applicable in its present form to developments in pristine or near-pristine habitats.

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VI - SHIPPING

The Green Marine Program

David Bolduc, Green Marine, presented by Jason Scherr, Port of Prince Rupert

Green Marine is a voluntary industry-based sustainability partnership initiative that seeks to reduce the environmental footprint of marine shipping operations. The program began in October 2007, and now has over 187 North American participants (Table 2). These include ship operators, port authorities, terminal operators, industry associations, and shipyards.

Table 2: Growth in the four categories of participants in the Green Marine program since 2007.

Categories	2007	2013	Composition
Participants	34	73	Ship owners, port authorities, St. Lawrence Seaway, shipyards
Partners	23	58	Companies having business links with the marine industry or to the maritime sector
Supporters	19	44	Governments, cities and municipalities, ENGOs and other NGOs
Associations	7	12	Canadian and US maritime associations representing more than 500 maritime companies in North America
Total	**83**	**187**	

Currently the Green Marine program addresses nine major environmental issues: invasive species, greenhouse gas emissions, other air emissions, cargo residues, oily water, community issues (dust, noise, light, and odours), water and land pollution prevention, environmental leadership and garbage management. For each environmental issue, the performance of participants is evaluated using a scale from 1 to 5, with 1 equating to operations that are following current regulatory compliance, and a score of 5 applied to those showing excellence and leadership in best practices, integrated management systems, and the introduction of new technologies. This independent certification scheme is developing benchmark tools to measure performance, and strives to promote a culture of continuous improvement. Table 3 shows an example of the scoring system for the issue of greenhouse gas emissions. In 2008, the average results of participants across all 8 environmental issues was 2.0 and it has steadily increased to 2.95 in 2012, during which time membership in the program has increased significantly, and the requirements from the program have become more stringent.

Green Marine membership is expanding on the west coast and now has 30 members (Table 4). A West Coast Advisory Committee has recently been established and includes industry participants in the program as well as representatives from government (Transport Canada and Environment Canada) and NGOs (WWF Canada and the Vancouver Aquarium). The committee's mandate is to oversee the implementation, development and revision of the Green Marine environmental program. It will advise and make recommendations on priority and regional environmental issues, as well as develop performance indicators for all of the four categories of participants and address any other relevant information relevant to the development and improvement of the Green Marine program.

The first West Coast Advisory Committee meeting was held on May 29, 2013 in Vancouver. Its priorities for 2013 are to:

- develop a 3 year work plan for environmental program expansion, including adapting the program to the realities of issues on the west coast, and
- considering adding underwater noise and marine mammal protection to the list of the program's environmental issues, and to
- discuss the capacity of industry to address these issues.

Table 3: Green Marine scoring system for greenhouse gas emissions for a port or terminal operator.

Level	Criteria
1	• Regulatory compliance
2	• Limit idling of vehicle engines • Promote sustainable practices by employees • Implement measures to reduce congestion and idling during periods of heavy activity • Inform or issue, when necessary, warnings to ships which emit excessive amounts of smoke
3	• Conduct annual GHG emissions inventory
4	• Adopt an energy performance plan for reducing GHG and air pollutants
5	• See a continuous reduction of the port's or company's direct GHG emissions (in intensity)

Table 4: Membership in Green Marine on the west coast.

Shipping Companies	Seaspan ULC Island Tug and Barge Ltd. SMIT Canada Inc.	**Shipyards**	Vancouver Drydock Vancouver Shipyard Victoria Shipyards
Ports	Nanaimo Port Authority Port Metro Vancouver Prince Rupert Port Authority Greater Victoria Harbour Authority Port of Seattle	**Partners**	Quickload CEF Inc. Envirochem Services Inc. Ventus Hemmera Tidal Transport & Trading Ltd. Blue Seal Inc. RBM HoldSolutions Progress Energy Canada
Terminals	Neptune Terminals Ridley Terminals Maher Terminals Squamish Terminals Fraser Surrey Docks Kinder Morgan Canada	**Industry Associations**	Chamber of Shipping of BC Council of Marine Carriers
		Supporters	WWF Canada Vancouver Aquarium Northwest Community College

Underwater Noise Mitigation for Shipping and Pile Driving
Lindy Weilgart, Dalhousie University

Background noise levels have doubled every decade for last 6 decades in some areas, mainly from shipping. The largest source of noise from large ships is propeller cavitation (Figure 14). Reducing cavitation may decrease fuel consumption, air emissions, and maintenance costs. Reducing noise by 6 dB from the loudest 16% of all vessels results in a 60% reduction in the ensonified area. Merchant ships currently differ by 40 dB between the quietest and the noisiest vessels, showing there is room for improvement.

Reduction of cavitation levels by 6-10 dB is currently feasible, but greater reductions require further research. Modeling basin studies/optimization for large commercial ships is beneficial to reduce noise, likely only representing <2% of the total vessel cost. Most improvements can be done at the design stage for new ships vs. retrofitting old ones. Noise has never been a consideration for designing merchant ships. Only the large ships use model basins in their design phase, and only 5% of new ships use propeller cavitation model testing during design. To reduce cavitation, as uniform a flow into the propeller as possible, i.e. a uniform wake field, is needed.

The noisiest merchant ships are probably not operating at optimal efficiency. An increase in efficiency of 5-10% yields an annual savings of $500,000 to $ 2 million for most merchant ships. The International Maritime Organization (IMO) recommendations focus on quieting propulsion through propeller design/modification to reduce cavitation, hull design flow noise reduction, but especially hull/propeller optimization for a uniform wake field, on-board machinery damping, vibration isolation mounts, and equipment isolation, and on operational modifications such as speed and load variations, and maintenance. For the latter, establishing a routine inspection and maintenance program to identify and correct conditions that increase ship noise is recommended.

Propeller inspection and cleaning should be carried out as marine fouling worsens cavitation and reduces efficiency. The condition of machinery should be monitored as normal degradation of pumps and other rotating machinery often produce increased vibration and noise levels. In general, noise reduction efforts should focus on ships with tones (often from propeller nicks), older ships, and reducing vessel speed.

The Cavitation Inception Speed, over which a propeller cavitates, is around 10 kts for most merchant ships. For the vast majority of ships, a decrease in speed results in a decrease in noise, with the exception being variable or controlled pitch props (CPP) with fixed shafts. However, vessel speed reduction should consider cumulative noise in an area, i.e. there is a trade-off between source level reduction and the time spent in a region. For one ship, operating at 7.7 kts or at 35% of the ship's operational speed, produced the minimum source level with the minimum time spent in an area. Real-time monitoring of shipboard noise and vibration can provide real-time feedback to ship operators on ship noise levels. These cost-effective monitoring systems can be incorporated into newly designed ships or back-fitted to existing ships. Shipboard vibration sensors should be placed at noise critical locations such as the hull above propellers for cavitation noise, or directly on main machinery noise sources. These vibration sensors together with a one-time ship radiated noise test can provide real-time ship noise estimates, giving operational guidance and tracking of degradations indicating maintenance may be required.

For the future, the IMO Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP) should be carried out in concert with noise reduction, as noise measurements may point to energy efficiency issues. Model tank testing also should incorporate noise as matter of routine. A requirement to measure each ship's noise output would help to bring noise considerations to the fore. Research needs include comparing model tank tests with real at-sea measurements of ships in typical operating conditions.

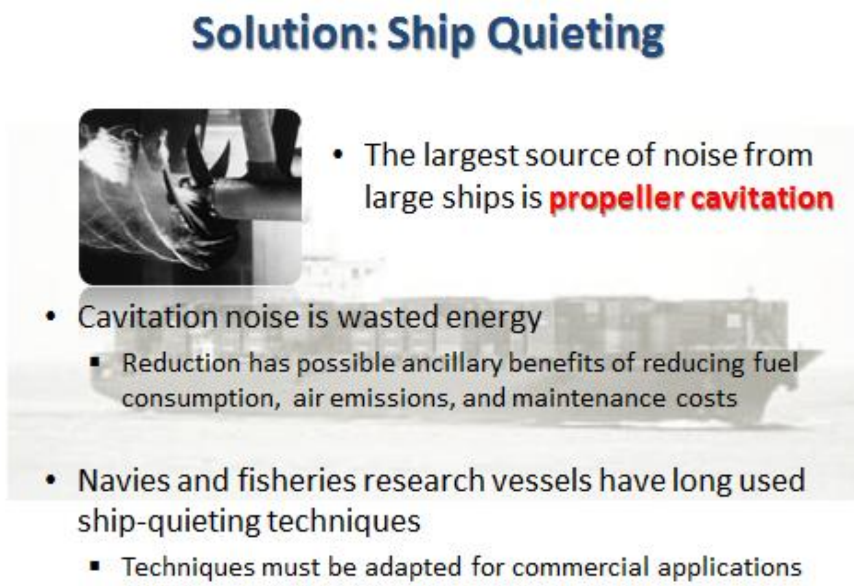

Figure 14. The main source of underwater noise on most vessels is due to propeller cavitation. Courtesy of Lindy Weilgart.

To reduce their noise impact, ships could minimize the time spent near shore, where noise propagates into the deep sound channel. IMO guidelines will provide a checklist for ship designers to consider noise. Noise compliance could be achieved through port authorities, ship classification and green certification programs, regulations, and economic incentives. A menu of quieting options for future consideration and action would be helpful, as would funds for modelling basin research.

For pile driving, quieting options include piling with a sound shield, the Hydro Sound Damper, dewatered cofferdams (noise reductions of around 20 dB), and bubbling curtains. However, sound transmission also occurs through the substrate, so rather than reducing noise after it is produced, quieter piling sources are recommended, such as the Multiple Linked Hydraulic Vibratory Hammer System (MLHVH) or drilled foundations using excavation machines, which are more than 40 dB under the German government noise limit (160 dB (SEL) / 184 dB (peak) @ 750m).

The Role of the International Maritime Organization in Developing Standards for Shipping
Linda Nowlan, WWF Canada

While there are no comprehensive global rules on underwater noise, the International Maritime Organization (IMO), the UN agency that governs the world's maritime shipping, has been developing draft *Guidelines for Minimizing Underwater Noise from Commercial Ships* for the past five years, proposed to be adopted in 2014. The Guidelines are voluntary, and focus on vessel quieting technology. This presentation addressed six issues:

- Described the IMO.
- Provided a timeline of development of the new Guidelines to minimize underwater noise from ships.
- Highlighted the 'out of scope' issues not included in the Guidelines.
- Described how Guidelines can change national practice.
- Highlighted other IMO procedures to reduce ship noise.
- Emphasized that the IMO is only one part of the international law toolbox to minimize underwater noise.

Description of the IMO
The IMO was established in 1958 as a specialized agency of the United Nations with the responsibility for safety and security at sea and the prevention of marine pollution from ships. Its motto is "Safe, secure and efficient shipping on clean oceans". The IMO has adopted 40 Conventions, numerous Protocols, codes and recommendations relating to safety, pollution prevention, security, liability and compensation. The most important IMO environmental treaty is the International Convention for the Prevention of Pollution from Ships (MARPOL, 1973) and its modification Protocol (MARPOL, 1978). The IMO's work is carried out by a number of committees and sub-committees overseen by the governing bodies of the Council and the Assembly. IMO's senior technical body on marine pollution, the Marine Environment Protection Committee (MEPC), is aided by a number of Sub-Committees, such as one devoted to Design and Equipment (DE).

Timeline of Development
Underwater noise and its adverse impacts on marine life were recognized as an issue requiring guidance from the IMO starting in the mid 2000s. The US submitted an Information Paper to MEPC in March 2008. In October 2008, MEPC established the first correspondence group (CG) on this topic which issued two reports to MEPC 59 and 60. At the October 2010 meeting, the MEPC agreed with the CG's recommendations to develop "Non-binding, technical guidelines and consideration of solutions to reduce the incidental introduction of underwater noise from commercial shipping and, in turn, reduce potential adverse impacts to marine life". The areas to be assessed for potential underwater noise reduction included propulsion, hull design, onboard machinery and operational modifications.

In Feb. 2012 at DE 56 a second Correspondence Group on" Minimizing Underwater Noise" was established to develop the non-mandatory draft guidelines for reducing underwater noise from commercial ships. This CG, led by a US Coast Guard representative, included a number of state, shipping, and NGO sector representatives. Transport Canada was a CG Member and received input on the Government of Canada's position from DFO, the Canadian Shipping Federation, Natural Resources Canada and WWF- Canada.

The CG prepared a report for DE 56 in Dec. 2012 with draft Guidelines for reducing underwater noise from ships**.** Full consideration of the Guidelines and report was deferred to the next MEPC meeting in March 2014.

Scope of Issues Not Addressed in Guidelines
The report stated that a number of issues were beyond the CG's terms of reference, such as:

- including a specific noise reduction target, evaluating the contribution of underwater noise from vessels and other sources (land based, drilling, ice breaking etc.) so that mitigation can be directed at the largest contributor(s);
- quantification of the relationship between individual ship noise and regional ambient noise level reductions; **c**ontinued progress in quantifying and understanding the adverse impact of noise on marine species;
- setting operating Guidelines for sensitive marine areas that have significant noise issues where specific operational and/or design measures may be needed to fundamentally reduce underwater noise from ships that operate there regularly, because of their impact on marine life;
- identifying the types of areas and situations when waterborne noise is most disruptive for marine life (near shore, during migration, ice breaking, etc.);
- using standardized measurement protocols to develop noise profiles for each ship type under different operating conditions;
- identifying the noisiest ships to gain a better understanding of the factors that elevate the noise levels of these ships;
- establishing baseline ambient noise levels in ocean areas of key concern such as those with high levels of marine biodiversity where shipping activities are forecasted to rapidly increase; and
- collecting and providing information on sensitive areas, including well known habitats or migratory pathways, to ship masters and owners for the purpose of voyage planning.

These issues will be considered by MEPC.

How Guidelines Can Change Canadian Practice
The proposed IMO Guidelines provide an important, but limited, contribution to marine environmental protection: they are non-binding, and impose no legal obligations upon IMO member governments such as Canada, until the obligations are incorporated into domestic legislation. The Guidelines can be incorporated into national legislation, such as the *Canada Shipping Act*, at a future date. They could also be adopted by industry, and included in port and industry incentive programs such as Green Marine. Eventually the Guidelines could be made into binding international law. There is as yet no agreement on where in the IMO legal structure the Guidelines best fit.

Other IMO Options to Address Underwater Noise
Other IMO options to address underwater noise exist, such as rerouting ships. To secure vessel-navigation regulations, policies, or modifications, from the IMO, a Member State must develop and submit a formal proposal.

Particularly Sensitive Sea Areas (PSSAs) are a tool with potential application to underwater noise. Examples include some of the world's most spectacular marine areas like Australia's Great Barrier Reef, the US Florida Keys, and Ecuador's Galapagos, which are vulnerable to damage by international shipping activities. The IMO Guidelines for PSSAs requires the area to meet at least one of the following criteria: (1) ecological criteria such as uniqueness or rarity of an ecosystem, diversity of an ecosystem, or an ecosystem's vulnerability to degradation by natural events or human activity; (2) social, cultural and economic criteria such as the significance of the area for recreation and/or tourism; and (3) scientific and educational criteria such as the provision of baseline criteria for biota. The process for designation is that the IMO Member Government leads the process and submits a PSSA application to the IMO's Marine Environment Protection Committee (MEPC). Once a PSSA is in place, ships transiting the area are subject to "Associated Protective Measures" which define the means by and the extent to which a PSSA is protected against environmental threats posed by international shipping and can include restrictions such as zero discharge or routing measures.

Many of these measures can be sought by a national government at the IMO without a PSSA application. Routing measures under Regulation 10 of Chapter V of the International Convention for the Safety of Life at Sea (SOLAS) include a number of options such as Areas to Be Avoided (ATBAs) which are areas within defined limits that should be avoided by all ships or certain classes of ships, in which navigation is particularly hazardous or in which it is exceptionally important to avoid casualties. ATBAs have been used in Canada but so far only to prevent ship strikes of cetaceans, rather than to address the general threat of underwater noise.

The IMO Is Only One Part of the Toolbox

The IMO and international shipping laws are just one part of the international toolbox to minimize underwater noise. The toolbox also includes the United Nations Convention on the Law of the Sea (UNCLOS), the International Whaling Commission (IWC), the Convention on Biological Diversity (CBD), and the Convention on Migratory Species (CMS). A 2012 comprehensive report from the CBD summarized the applicable legal instruments and science related to the impacts of underwater noise on marine life.

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The IMO and Potential Solutions for BC: General Discussion

Discussion facilitated by Richard Holt, Environment Canada; Summary by Kathy Heise, Vancouver Aquarium

This was a group discussion to follow up on any questions based on the previous presentations during the morning of day 2, beginning with a conversation around the IMO. The following is a synthesis of that discussion.

Transport Canada is the head of the Canadian delegation to the IMO. It receives advice from DFO, Environment Canada and WWF. There has been a great deal of success reducing airborne pollutants from the commercial shipping sector through IMO agreements, and that this could serve as a model for initiatives to reduce underwater noise pollution. Success in reducing airborne pollutants was based on a number of factors:

- Advocates had to present a very strong technical case for the need to reduce emissions, and the adverse consequences of maintaining the status quo. They modeled the benefits of how change would improve air quality.
- Advocates had to demonstrate that shipping was a significant source of airborne pollutants.
- They also had to demonstrate that the shipping industry wasn't being singled out, and that governments were also taking action on other sources of airborne pollutants.
- At least 2/3 of the countries involved, as well as countries that account for 50 % of the shipping tonnage (flag states) had to support the vote.
- Over time, support for the initiative developed from within the shipping industry.

Developing industry support was also critical to moving a shipping lane on the east coast in order to avoid important areas for right whales. A stewardship area was established, and vessels were asked to avoid this area and were tracked using AIS. During the first year, 98% of vessels complied, and congratulatory letters were sent to owners, which also served the purpose of reminding the shipping companies that they were being watched. In the 2nd year, there was nearly 100 % compliance in avoiding the stewardship areas.

Despite the efforts of many, implementing solutions to problems through the IMO process presents numerous challenges as well. Decisions for action may be just as politically based as science based, and as a result there may be delays in the process. This happened recently with the delay of the introduction of nitrogen oxide (N0x) emissions limits for ships from 2016 to 2021, due to heavy lobbying, primarily by Russia. Spatial measures, such as moving shipping lanes, require IMO approval, but other measures, such as speed reductions within a certain distance from shore, do not.

The IMO's Energy Efficiency Design Index (EEDI) and greenhouse gas (GHG) emission standards are relatively new, and new ships that are constructed should be evaluated to assess whether their underwater noise contribution is reduced relative to other vessels in the same class. It is expected that ships constructed to EEDI standards will have reduced fuel costs, so the program isn't necessarily a hammer- it can provide real financial incentives to owners. This is an important opportunity to collect data on quietened vessels, which could be used to help prescribe standards for underwater noise emissions.

VII - BREAKOUT GROUPS (Summarized by K. Heise)

A. Acoustic reserves as a strategy to reduce the impacts of underwater noise: where should they be located? Are they appropriate for the Douglas Channel/Caamaño Sound area?

An acoustic reserve should be an area that has reduced levels of anthropogenic underwater noise. To be effective, baseline noise data should be collected, with hydrophones used continuously to monitor any changes in noise levels over time. These data would ideally be used to manage such noise changes, and maintain ambient noise near initial baselines (or lower). The distribution, abundance and movements of key species such as whales should also be monitored, and mitigation of noise undertaken when needed. Acoustic reserves as stand-alone zones do not exist at present. The process of implementation will likely take a long time, but they could have the advantages of – or could be included in – MPAs. Of the 575 MPAs found globally that include some consideration of cetacean habitat requirements, only a few of the US National Marine Sanctuaries provide protection from noise. For example, in the Stellwagen Bank National Marine Sanctuary shipping lanes were shifted to reduce the risk of ship strikes and to decrease the impacts of vessel noise on the endangered right whale population. In eastern Canada, the Gully MPA provides some protection from noise for northern bottlenose whales through a 10-km buffer zone excluding seismic activity and MPA zoning which restricts various noise producing activities within the MPA (but not outside it, which is an issue given the long distances travelled by lower-frequency sound underwater). A significant challenge to establishing acoustic reserves is that marine planners do not currently tend to consider the underwater soundscape in their approaches, and it is not mentioned within planning guidelines. This reflects the general lack of awareness by managers that underwater noise is an issue for marine animals, and outreach initiatives are required if this is to change. In BC this situation is changing: marine plans currently under development refer to this threat, and propose measures to guard against excessive noise; see section C below.

This breakout group felt it was preferable to consider multiple pathways to creating low noise areas rather than trying to apply a single approach to create acoustic refuges,. One approach recommended by the group was to start with relatively easy to implement quiet areas, such as within an existing or in-progress MPA or National Marine Conservation Area. In such an area, a monitoring plan should be developed to assess any changes in noise levels, and, ideally, to identify noise sources in order to minimise or eliminate increases. These efforts could be accompanied by educational outreach on the effectiveness of the quietening in terms of benefits to marine life, with a goal of broadening awareness of the effects of underwater noise. The following were some suggested approaches:

- Focus on keeping currently-quiet areas quiet by limiting human activities. Consider restricting vessel size/type/speed while in the area. These areas could be important for species beyond cetaceans, such as spawning or rearing habitat for fish.
- In areas of heavy human use that overlap important habitats, consider actions that would reduce the total amount of noise animals are exposed to (a restorative approach). Look at areas from a species-specific approach (e.g., quietening for killer whales in areas frequently occupied by them, especially critical habitat) or from a human use standpoint (e.g., quietening a harbour).
- In areas of seasonal importance to species and ecosystems, temporal acoustic reserves could be considered. This would also increase public awareness of the underwater noise issue. This could be a similar approach to fishery closures. This approach might be appropriate in areas of intense whale-watching, where for a specified amount of time no whale-watching is permitted.

- Consider a zoned approach, with a core area within which there is no noise generating activity. In a zoned approach, consider excluding certain activities in the core (e.g., motorized vessels, construction) surrounded by a buffer zone with reduced noise requirements, e.g., speed restrictions. The US National Oceanic and Atmospheric Administration (NOAA) was considering development of no-vessel zones in the San Juan Islands for the protection of killer whales, however these zones were not, in the end, adopted.[8] On the Stellwagen Bank National Marine Sanctuary, right whale feeding areas receive some protection by re-routing shipping lanes and restricting vessel speed. The primary goal of these restrictions is to reduce or eliminate ship strikes of whales, but they have the ancillary benefit of reducing noise.
- Participate in the International Quiet Ocean Experiment (IQOE), organized by the Scientific Committee on Oceanic Research and the Partnership for Observation of the Global Oceans. The IQOE proposes to scientifically experiment with reduced levels of anthropogenic noise and study the consequences on marine life. The science plan has not yet been published for the IQOE, but the concept is similar to the IUCN Dark Skies campaign, which seeks to reduce light pollution.

The group discussed some potential locations for quietened areas, incorporating existing work that has been done to identify biologically important areas, such as the 'Marine Priority Conservation Areas: Baja to Bering' (B2B) initiative, Ecologically and Biologically Significant Area (EBSA) designation, critical habitat, etc. Specific areas that were discussed are listed in the Workshop Recommendations section following this one.

The need to establish a framework for determining approaches to identify areas for quietening was identified. Education and outreach is essential to move this issue forward and the need for a mascot was identified – a killer whale was suggested. In general, management of underwater noise in BC could be framed around the need to protect critical habitat for one or more whale species on Canada's Pacific Coast, with SARA-designated critical habitat (or candidate or proposed habitat) being an initial subset of habitats for consideration for acoustic protection. Criteria used at the workshop to identify potential quiet MPAs were: (i) levels of ocean noise from shipping (modeled data), (ii) levels of human activity in the area and the resultant impact (modeled data)], (iii) presence of important or critical cetacean habitat; and (iv) presence/absence of existing protection or proposals for protection in each area. Some secondary considerations include habitat value and levels of biodiversity (other species), and presence of hydrophones in the area. Cetacean habitat was used as a primary consideration because spatial data were available on the locations of important and critical habitat, and because of the effect of shipping noise on cetacean hearing, vocalizing and foraging.

B. Noise standards for BC and Canada: what is appropriate? What role is there for incentivizing reduction or quieting technologies?

The main focus of discussion in this breakout group was on shipping noise, with recognition that the *Statement of Canadian Practice on Seismic* provides minimum mitigation requirements for seismic surveys and that pile driving standards are implemented regionally, often based on outdated criteria. Within DFO there is a general tendency to follow US and/or the UK's Joint Nature Conservation Committee (JNCC) protocols for project assessment, and for managers to apply these criteria for recommended mitigation measures regionally – there are no national standards for how projects are

[8] http://www.nwr.noaa.gov/publications/protected_species/marine_mammals/cetaceans/killer_whales/recovery/kw_regs_guidelines_march_2013.pdf

reviewed. If a species is not listed under SARA, there are relatively few tools that can be used to require mitigation. These existing tools are described in the background document in Appendix 4, *An overview of ocean noise regulation in Canada.*

There was consensus that strategies to manage underwater noise should be area based, rather than species based, and that such strategies should focus on overall noise reduction targets, recognizing that many species of marine animals are vulnerable to the impacts of noise. The EU's Marine Strategy Framework Directive (see Weilgart's abstract, this report) approach, with modifications, may be appropriate. Within critical habitat for SARA-listed species, threshold targets should be set even lower within the sound frequencies of interest (i.e., where frequencies of underwater noise overlap with those of listed species).

Important to this discussion was the recognition that in general, the faster a ship travels, the more noise it makes. Speed reduction targets may make sense, particularly when linked with real-time acoustic monitoring of individual vessels (e.g., so that inbound vessels can be required to slow to their quietest operating speed, or address noise-generating problems such as a damaged propeller). 'Sound credits', like carbon credits, may be a good incentive, although the general drawbacks identified for carbon credits may also apply here. Incentive based programs can complement the enforcement of regulations with penalties. Regulations are usually necessary to motivate the small proportion of users who choose not to comply with voluntary guidelines.

For the purposes of this discussion, it was important to appreciate that that commercial vessels use different economic models: container ships pay for anchorage, so they tend to slow down to delay arrival and avoid paying excess port fees, whereas bulk carriers are individual charters with arrival time commitments, so they don't slow down to fit berth schedules. As they travel at higher speeds, bulk carriers are therefore unnecessarily noisy, and spend more time at anchor, where fouling can become an additional source of underwater noise through the generation of a source of increased drag on the hull. An indirect way to address this is through provision of ship-specific information on fuel efficiency that shows the cost savings inherent in slower operating speeds, along the lines of one of the environmental ratings offered by RightShip (www.rightship.com). Similarly, the individual real-time noise monitoring mentioned above would provide information that would allow for port-based financial incentives around noise reduction. Such incentives should be set to discourage the increased noise of faster vessel travel.

The IMO has standards for airborne noise levels for ships, and energy efficient design requirements, as well as proposed voluntary guidelines for underwater radiated noise levels. The latter are likely to be approved in March 2014 (see Nowlan's abstract, this report). Because there is a direct physical link between vessel noise generation and energy efficiency (e.g., hull drag both decreases efficiency and generates noise; damaged propellers work less efficiently and cavitate more), there is motivation for ship owners to be proactive and reduce their underwater noise footprint. Voluntary standards such as these IMO Guidelines can help reduce noise quickly. In North America, the Green Marine program has potential to be a leader in this initiative as this association is considering adoption of a criterion on underwater noise reduction. The IMO Guidelines could provide an initial benchmark for this criterion. Regulations often evolve from guidelines and are needed to motivate the vessel owners or operators that are not participating voluntarily. This is how the air emissions standards evolved. Within Section 5 of Canada's *Shipping Act*, ports are able to issue tickets around air emission violations, and enforcement falls within the jurisdiction of the Port, as well as under Transport Canada. This model could eventually be applied to address noise emissions from individual ships.

There are multiple approaches that could be used for quieting shipping. Discussion covered the following points:

- Incentive programs are a primary step to reducing underwater noise in the commercial shipping industry.
- Considering noise reduction during vessel maintenance is also important. Maintenance options for noise reduction include propeller and generator repair, and retrofitting generator baffles or noise reducing mounts. Ship owners and operators should use maintenance approaches and the best available technologies to quieten their vessels, and new ships should follow the IMO Guidelines, which focus on new ship construction.
- Ship sound measuring stations, similar to the weigh stations used for transport trucks, would be a useful tool for ports to use in measuring real-time noise levels per vessel. This could be implemented by ships transiting between two hydrophones so that source levels could be determined. Noise reduction measures stemming directly from this approach could include directions from Vessel Traffic Services for monitored ships to slow down to their quietest (safe) operating speed. Noise recordings or live monitoring would also allow for the identification of problem vessel components, e.g., a damaged propeller. Such data could also feed into a port-based incentive programme as described above. A drawback of this approach is that operators could choose to "cheat" by shutting down some noisy equipment (e.g., generators) while transiting the sound station, resulting in inaccurate source level data.
- Another way of monitoring underwater radiated noise would be to install tamper-resistant noise monitoring devices on board (along the lines of Automatic Identification System (AIS) transponders installed on commercial and passenger vessels). Data would be recorded and stored continuously, and downloaded when the ship arrives in port. This way the overall contribution of the ship to ambient noise could be used in an incentive program. Disadvantages with this system include difficulties in ensuring tamper resistance, and the fact that a single vessel-based point source is not optimal for recording a ship's noise profile.
- The Green Marine program could be a platform for both noise reduction and increasing industry awareness of underwater noise pollution, if a criterion related to noise was included in its rating scheme.

C. Marine plan implementation. Given current processes, how should marine spatial planning processes and government incorporate underwater noise considerations in development plans? What would be the priorities?

Three concurrent large-scale planning processes are in progress in BC. Two are focused on the north and central coast: the Pacific North Coast Integrated Management Area (PNCIMA – a federal initiative), and the Marine Planning Partnership for the North Coast (MaPP – a bilateral provincial/First Nations initiative). The third is the West Coast Aquatic (WCA) process, focused on the west coast of Vancouver Island. Smaller-scale initiatives, e.g., management plans for marine protected areas, including National Marine Conservation Areas (NMCAs) such as Gwaii Hanaas and the proposed Southern Strait of Georgia NMCA, could also incorporate underwater noise considerations. Small geographic areas can still provide some measure of acoustic protection depending on their geography, e.g., if there are islands that can provide 'acoustic shadows' that reduce sound transmission.

These planning processes are long term, with implementation expected to take 10-20 years. As a result, they need to anticipate future research needs and to be adaptive, and at least consider noise thresholds in their Ecosystem Based Management standards. A risk assessment framework, such as those discussed in workshop presentations, may be most appropriate.

There are a number of ways to influence underwater noise associated with shipping within the marine planning process:

- Marine plans could specify noise objectives and set cumulative noise caps regionally. Local communities should be engaged to ensure grassroots support.
- Within a planning area, baseline underwater noise levels should be established using standardised approaches, with ongoing monitoring and risk assessments undertaken under different scenarios of development.
- Marine plans can create zones with different objectives for each zone. This is the approach that MaPP is using.
- Underwater noise (measured or modelled) should be a layer in spatial data sets. Modelled noise levels should be validated with measurements, and objectives set for maintaining areas of low noise as required to meet conservation targets.
- In efforts to establish a network of MPAs, spatially linking acoustically quiet areas would be beneficial.

Other tools such as the Green Marine program (described above), species management regulations (based on SARA-listed species and other species ranking criteria, e.g., provincial Red and Blue lists), the IMO's voluntary noise control standards, and changing ship design to improve efficiency would also help to reduce underwater noise within the context of marine planning.

Requirements of the commercial shipping sector and its international regulatory structure need to be taken into account. Shipping is an international industry, regulated primarily at the international level, though Canada has considerable scope to regulate within territorial sea limits.

Obtaining Particularly Sensitive Sea Area (PSSA) designation from the IMO could be a useful approach to protecting key areas of habitat. To date, the IMO has designated 13 PSSAs, including some of the world's most spectacular marine areas like Australia's Great Barrier Reef, the US Florida Keys, and Ecuador's Galapagos, which are vulnerable to damage caused by various aspects of international shipping activities. These are science-based designations but require governmental support and involvement in the multi-year assessment and designation process. However, once designated, ships transiting the area are subject to restrictions, which can include zero discharge zones and no-go zones; see Nowlan abstract for details).

The noise-related priorities in planning should be:

- Undertaking risk based assessments, and in areas of critical habitat, refining noise-related data layers and establishing target thresholds that are based on best up to date information;
- Engaging in a broader educational outreach to all who introduce noise into the ocean;
- Piloting a site for a cumulative effects assessment of underwater noise levels;
- Determining a cumulative noise cap for coastal waters, in addition to maximum exposure criteria; and

D. What could we achieve within the next five years within BC?

This discussion focused on shipping as a source of underwater noise, and options to manage and mitigate it, and concluded that standards for ports, proponents and regulators are achievable within the next five years. There are multiple approaches that could be used to achieve these changes. Education is key, as without a general awareness of the potential impacts of underwater noise on marine life there will be little appetite for change. The Green Marine program has the potential to make progress in this regard. Although this is a port-specific rather than coast wide program, it may be able to generate changes in vessel noise profiles that have benefits across a vessel's operating area (e.g., via incentivising improved propeller maintenance).

Monitoring is also important both for determining current noise levels and understanding their sources. Using hydrophones for monitoring is a first step in this process, as well as in advancing education and outreach. Hydrophone monitoring is already being done by the Port of Metro Vancouver, and British Gas (BG) has hydrophones around the Port of Prince Rupert. However, the data collected are not necessarily publicly available. Ideally, a responsible agency would establish noise-monitoring stations, similar to truck weigh stations, which vessels would pass over in transit. The Salish Sea Hydrophone Network has characterized the underwater noise levels of hundreds of individual ships, and this information could be used as a basis for public education and informing ship owners about their contribution to the underwater soundscape. Similar data have been collected by DFO at its Salish Sea hydrophone sites, but have not yet been analyzed. There have not been any publicly-available data collected in shipping lanes, and this is an obvious data gap.

Once hydrophones are in place to monitor individual ships as well as to characterize overall noise levels, a number of approaches to reduce noise are possible:

- Use existing data on noise output from different sizes and classes of vessels, and establish percentage criteria below which ships should fall. Vessels above the criteria would face pecuniary consequences, e.g., higher port fees. A per vessel approach will not address the overall increases in noise that could result from port growth and related increases in shipping traffic, so an approach to address cumulative or total noise levels must also be considered (see following bullets);
- Shipping noise should not be allowed to reduce whale communication space beyond a certain percentage, perhaps based around percentages used in other jurisdictions (e.g. Hatch et al., 2012). Masking is a significant threat to marine animals.
- Establish a cumulative noise exposure level, similar to the EU MSFD approach, rather than only maximum event-based exposure criteria for individual populations.
- Develop a report card system that identifies the noisiest 10% of vessels passing over a noise monitoring station. In the absence of legislation, letters could be sent to vessel owners advising them of their noisy ships, and a list of worst offenders could be published. Letters could also be sent to the owners of quiet ships, congratulating them on their reduced contribution to the soundscape.
- Ports could adopt maintenance requirements for noisy ships, as poor vessel maintenance is the source of extraneous noise on ~10% of merchant ships.
- A mandatory phased-in program could be established to incentivize quietening technologies for retrofitted vessels. Proposed new projects could require quietened ships. (This assumes that the IMO voluntary guidelines will pass in 2014.)

- In order to generate additional solutions, there should be more direct discussion among ports, those involved in marine policy, and proponents of action on quieter oceans.

Following the examples set by Green Marine on other environmental issues, a phased-in approach could be applied with the highest standards. For example:

Level 1: New ships comply with IMO Voluntary Guidelines on Noise
Level 2: New ships surpass IMO Voluntary Guidelines on Noise
Level 3: Ships report their underwater noise levels.
Level 4: Real time monitoring systems are used by the port for a noise quietening incentive program.
Level 5: Vessels comply with the IMOs Energy Efficiency and Design Index for new ships, and the Ship Energy Efficiency Management Plan for all ships.
Numerous opportunities exist for education and outreach. The producers of underwater noise, (commercial ship owners and operators, BC Ferries, recreational vessel owners, whale-watching vessels, pile drivers, etc.) could benefit from an increased understanding of the problems associated with underwater noise. A follow-up workshop could be offered to share best practices for noise reduction. This could be a joint initiative of various interested organisations such as WWF Canada, Natural Resources Defence Council, the Vancouver Aquarium, and Green Marine.

Underwater noise awareness could benefit from a mascot and as described above, the killer whale was suggested as an iconic species with a widespread distribution and one that lives in a world where the quality of the acoustic environment has real consequences for its survival. There is also a real need for a current literature synthesis to update previous work.

Within the next five years, long term monitoring with calibrated hydrophone systems should be expanded, and protocols for data collection and archiving should be established. A network of passive acoustic monitoring devices, similar to the approach taken for the Stellwagen Bank, may be a good model for this. DFO already has data from a number of hydrophone deployments, and these should be analyzed. There is a need for a gap analysis, to determine where acoustic baseline data are missing.

Other monitoring options that should be considered include the following measures:

- Proponents of development projects should collect and make public noise data to help characterize baseline noise levels on a year round basis (rather than using short term deployments).
- More work needs to be done to establish a provincial hydrophone network, and links made among citizen science networks such as Cetacealab, Orcalab and Pacific Wild, and government and academic listening stations and networks.
- Hydrophones need to be placed in critical habitat areas for aquatic species. A continuous monitoring system could characterize ambient noise and noise sources, and record current baselines.
- Ambient baselines should be established for key areas, based on existing data collected during various environmental assessments and multiple research initiatives (DFO, Ocean Initiatives, port developments, etc.).

Other miscellaneous approaches that were discussed included the following recommendations:

- Push for administrative actions. The federal government should pass the new Marine Mammal Regulations, and more actively support the completion of SARA recovery strategies, action plans, and critical habitat protection orders.
- Compare underwater noise levels of various classes of vessels constructed under the Energy Environmental Design Index with those of older ships to quantify changes to radiated noise levels. Model the implications of these differences are on a basin-wide scale to assess future noise levels.
- Evaluate the contribution of BC Ferries and whale-watching vessels to the underwater soundscape, and inform them of these results. Provide an opportunity for these operators to be proactive.

References
Hatch, L. T., C.W. Clark, S.M. Van Parijs, A.S. Frankel, & D. W. Ponirakis (2012). Quantifying loss of acoustic communication space for right whales in and around a US National Marine Sanctuary. *Conservation Biology*, *26*(6), 983-994.

WORKSHOP RECOMMENDATIONS

The primary conclusion of the workshop is that consideration of the underwater soundscape, and its importance to marine life, is critically important in marine management and planning processes in Canada's Pacific, and elsewhere.

The quality of the acoustic environment has real consequences for marine animals, because most of them use sound in the way that terrestrial animals use vision. In general parlance, 'pollution' is defined as the discharge of deleterious substances and energy into the natural environment, which includes both chemical contaminants and noise. Underwater noise must be managed accordingly. There are multiple pathways to manage underwater noise, although the properties of sound underwater that make it so conducive to communication also make it a challenging stressor to manage effectively. The topic of underwater noise is slowly beginning to receive more public and management-related attention, and while it has not been comprehensively addressed in many marine species recovery strategies or action plans to date (i.e., under the Canadian *Species at Risk Act* [SARA]), the situation is changing. It is precautionary to implement operational and technological quietening measures using what we know now, instead of waiting for more comprehensive guidance based on scientific research. Over the course of the workshop's two days, presenters and participants made multiple recommendations concerning management solutions to minimize and mitigate underwater noise. This concluding section is WWF's distillation and summary of those recommendations.

Translating Science into Policy

Recommendation 1: More work must be done to translate the science of underwater noise into policy and regulations to guide management decisions.

As reported in the first underwater noise workshop, the federal government is working to translate scientific advice on underwater noise into policy. Currently, some scientific guidance on noise is incorporated into species recovery plans, marine mammal regulations, federal guidelines for mitigating noise impacts produced by underwater seismic surveys and sonar, project environmental assessments, management plans for marine protected areas, and shipping and recreational boating requirements. Further recommendations include:

- Analyze existing DFO acoustic data (originally collected to provide information on cetacean presence) for the purpose of quantifying ambient noise levels along Canada's Pacific coast. This will provide an acoustic baseline (albeit already industrialized) that can be used as a reference to describe the quality of the marine environment, which can then be used to inform marine planning processes
- Establish national consistency in the protection of acoustic habitat. DFO uses a "Table of Activities Likely to Result in the Destruction of Critical Habitat" in assessing the potential impact of development and other activities. The attribute of 'sound exposure' in the Table requires threshold numbers based on the scientific literature, cross-jurisdictional comparisons and international best practices, such the EU's Marine Strategy Framework Directive.
- These exposure thresholds should be precautionary, and based on most recent scientific understanding, rather than just lifted from existing (and potentially outdated) documents from other countries. For example, US National Marine Fisheries Service thresholds for behavioural impacts on marine mammals do not consider masking effects and are 'overly simplified, scientifically outdated and artificially rigid'. Canadian marine managers and regulators should develop updated versions of these behavioural thresholds.

- Address masking, a significant threat to marine life, by limiting introduced noise to levels that do not reduce whale communication space below a certain threshold[9].
- In the absence of sufficient scientific information to determine the biological impacts of one or more projects, compensatory mitigation frameworks to ensure no net increase in noise levels in the soundscape should be considered. Net reductions in noise levels are preferable for busy areas.
- Strategies to manage underwater noise should be area based, rather than species based, and such strategies should focus on overall noise reduction targets, recognizing that many species of marine animals are vulnerable to the impacts of noise. Within critical habitat for SARA-listed species, threshold targets should be set even lower within the sound frequencies of interest (i.e., where frequencies of underwater noise overlap with those of listed species).
- There appear to be regional differences in the way Canadian Science Advisory Secretariat (CSAS) processes are used, demonstrated by the two CSAS studies presented at this workshop. The mechanisms by which findings from CSAS studies are incorporated into projects approvals in EAs, or in other management decisions or regulatory revision, should be transparent, and nationally consistent.

Impact Assessments

Recommendation 2: A new DFO policy on underwater noise, addressing projects' full acoustical footprints and incorporating cumulative impacts of multiple developments, should be developed to guide project proponents and regulatory decision makers.

Individual environmental impact assessments are insufficient to address underwater noise due to a lack of consistent requirements for monitoring and mitigation. A lack of standards means that proponents of industrial projects have inadequate guidelines when considering mitigation of project activities, and impacts of multiple projects are not considered cumulatively.

- The policy should move beyond safety zones and ramp-up restrictions to outline tools such as spatial or temporal closures, protected areas (e.g., MPAs, acoustic reserves (defined in the summary of Breakout Group A's discussion), NMCAs), use of noise-reducing methods (reduced ship speed and maintenance schedules and approaches that take noise reduction into account) and technologies (e.g., quiet ship designs, Vibroseis as an alternative to seismic, vibratory pile driving rather than impact hammers).
- Cumulative risk assessment frameworks should consider combined and interacting impacts from multiple projects, and for multiple ecosystem components, when evaluating noise-generating projects.
- Proponents of coastal development projects should be required to:
    - Use best available technologies for quieting wherever possible.
    - Undertake acoustic baseline monitoring across seasons and for more than one year in advance of their project.

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9 Note that specific reductions in whale communication thresholds were not discussed in any detail during the workshop. See Hatch et al. 2012 Conservation Biology 26: 983-994 for an analysis of the loss of right whale communication space in the Stellwagen Bank National Marine Sanctuary.

Surfacing fin whale. c. forwhales.org

Regulation of Underwater Noise

Recommendation 3: Revise and implement new regulations at different scales to improve underwater noise management.

The Canadian regulatory framework to protect acoustic habitat and address the stressor of underwater noise needs to be reviewed in order to provide a comprehensive response to this growing issue.

- At the smallest scale, regulations may be needed to protect the acoustic features of a SARA-listed species' critical habitat, e.g., southern resident killer whales in the Strait of Georgia.
- The revised Marine Mammal Regulations under the federal *Fisheries Act* set approach distances for whale watching boats and define 'disturbance' and will be a valuable addition to the regulatory toolbox. Once they come into force, these regulations should be implemented effectively, including regarding noise disturbance.
- Federal government action on an ocean noise Marine Environmental Quality regulation or standard under Canada's *Oceans Act* should be further explored as one potential comprehensive response.
- A policy goal of 'no net increase' in underwater anthropogenic noise (similar to the federal "no net loss" policy for fish habitat) should be considered by DFO at various spatial scales for areas of important habitat that are currently subject to low noise levels, and noise level reduction should be the goal for areas that currently surpass noise thresholds that are agreed to be harmful. (See Recommendation 1, above, for suggestions as to what might be found to constitute harm).

- The Federal government should support finalizing and publicizing the IMO draft *Guidelines for Minimizing Underwater Noise from Commercial Ships* in order to raise awareness among shipping industry groups.
- IMO's Marine Environmental Protection Committee (MEPC) should address the items listed as 'out of scope' of the above *Guidelines* document by developing future guidelines and regulatory policies that include a global noise reduction target and the inclusion of environmentally sensitive areas on marine charts.
- The proposed High Seas Biodiversity Agreement under discussion via the UN should address underwater noise, and acoustic refuges for the large whales that use deep sound channels for communicating vast distances should be protected through identification and designation of high seas MPAs.
- Designation of a Particularly Sensitive Sea Area through the IMO should be considered for an acoustically important area on the Pacific coast of Canada.
- The Province of BC should consider the use of IMO tools such as Areas to be Avoided for rerouting ships away from sensitive areas such as identified critical habitat.

Underwater Noise in Marine Plans

Recommendation 4: Marine plans should specify noise objectives, and set cumulative noise caps regionally. They should in part do this by engaging the local community to ensure grass roots support.

Comprehensive ecosystem based marine plans are under development in BC, and provide an opportunity to address underwater noise as a stressor on the marine environment. In particular, the Marine Planning Partnership (MaPP) is working to create new coastal and marine plans for the North Coast, the Central Coast, North Vancouver Island and Haida Gwaii, and develop and implement agreements that lay out specific guidance for day-to-day operations and marine use decisions in the plan area.

- Specific conservation targets could be included in marine plans, e.g., "Keep x % of primary habitat for y species in acoustically healthy condition." Or "Monitor baseline levels of ambient noise, and limit human caused noise-producing activities so that there is no net increase from 2014 measured noise levels."
- Cumulative noise exposure levels, in addition to maximum exposure criteria, should be used as targets as they typically benefit a broader range of species (whales, dolphins, fish and invertebrates).
- Exclusion of noisy activities altogether from certain habitat areas is a proven successful option, and should be considered in sensitive habitat areas in British Columbia.[10] Criteria for designating such areas could include their identification as critical or important habitat for at-risk species.
- Marine planning implementation agreements that will be negotiated between the federal, provincial and First Nations governments should address underwater noise minimization and mitigation.

10 For example, this approach has been used to ban sonar in the vicinity of the Canary Islands in response to beaked whale deaths and strandings. Fernández, A., M. Arbelo, and V. Martín. (2013). Whales: No mass strandings since sonar ban. *Nature*. doi:10.1038/497317d.

Killer whales. c. forwhales.org

Acoustic Monitoring
Recommendation 5: Noise monitoring should be expanded off the coast of BC.

- Noise levels should be monitored (using calibrated hydrophone systems) in representative areas coast-wide, recognizing that underwater sound transmission varies with depth, bathymetry, etc. Underwater noise data or modelled results should be a layer in the spatial data sets used by planners and managers, and modelled noise levels should be validated with measurements.
- Ambient baselines should be established for key areas, based on existing data collected during various environmental assessments and multiple research initiatives (DFO, Ocean Initiatives, port developments, etc.).
- Noise measuring stations should be linked to the AIS system to monitor source levels from individual vessels and identify the noisiest vessels in different ship classes. This could be a useful means of noise reduction around shipping lanes, as noise reduction measures could initially be targeted at these vessels. Since such noise reduction in part requires improved maintenance, vessel-specific noise reductions would affect their areas of operation, rather than just being local in effect (as would be the case with managing through slow-down requirements).

Acoustic Quieting and Marine Protected Areas
Recommendation 6: A quietened or quiet area, such as within an existing or proposed MPA in BC, should be designated in Canada's Pacific.

The need to establish a framework for determining approaches to identify areas for quietening was identified. In general, management of underwater noise in BC could be framed around the need to protect critical habitat for one or more whale species on Canada's Pacific Coast, with SARA-designated critical habitat (or candidate or proposed habitat) being an initial subset of habitats for consideration for acoustic protection. Marine protected areas offer promise as an underwater noise solution in some situations. This tool is not being used to its fullest. A review by Erich Hoyt (this workshop's keynote speaker) revealed that only 11 of 158 management plans for marine mammal protection had a reference to underwater noise. A question that has not yet been answered is how MPAs need to be configured to protect cetaceans and other species from noise. For example, how large must they be to provide noise protection in a given situation, and do islands and other land masses help to create effective buffers? These and other questions need to be answered in order to develop effective protected areas that address underwater noise.

- Initial considerations for designating quiet area MPAs were proposed at the workshop:
  (i) current levels of ocean noise from shipping (modeled data);
  (ii) levels of human activity in the area and the resultant impact (modeled data);
  (iii) presence of important or critical cetacean habitat, (used as a primary consideration because spatial data were available on the locations of important and critical habitat, and because of the effect of shipping noise on cetacean hearing, vocalizing and foraging); and
  (iv) presence/absence of existing protection or proposals for protection in each area.

  Some secondary considerations include:
  (i) habitat value and biodiversity; and
  (ii) presence of hydrophones in the area, i.e., availability of baseline noise data.

- Based on the above considerations, potential locations for quietened areas include, but are not limited to:

  - Juan Perez Sound (east side of Moresby Island in the Gwaii Haanas NMCA)
  - Fjordland Conservancy (marine planners are presently developing marine use plans in this provincial park)
  - Entrance to Juan de Fuca Strait (the Juan de Fuca Eddy – the US portion is protected as the Olympic Coast National Marine Sanctuary)
  - Scott Islands (a proposed National Wildlife Area and identified as a Marine Priority Conservation Area by the Baja to Bering initiative)
  - Douglas Channel/Caamaño Sound (has been identified as potential critical habitat for humpback and killer whales, and important habitat for fin whales)
  - Chatham Sound (potential critical habitat for killer whales seasonally)

- To meet noise-related criteria of an MPA, temporal and/or spatial speed reductions for commercial and recreational vessels could be used to reduce underwater radiated noise, especially in particularly sensitive areas or times of year (e.g., during herring spawning or high whale activity) and do not require IMO oversight to implement.[11]
- Topography needs to be considered in establishing new quiet refuge MPAs. MPAs in open water would need to be large due to the great distances that low frequency sound can travel under water.[12] In more confined waters, MPAs can theoretically be smaller, as islands and convoluted

[11] Vessels that travel below cavitation inception speed (8-10 knots for merchant vessels) will be quieter, unless they have variable pitched propellers. Vessels with large slow turning propeller blades tend to be quietest.

[12] The Canary Islands have a 50 nm exclusion zone for military sonar, and since its implementation, there have been no beaked whale strandings. See footnote 14.

shorelines may provide acoustic shadowing (depending on the location of shipping lanes and small vessel travel routes). Additionally, such protected areas should be set up with adaptive management considerations in mind. For example, such areas could be used to assess benefits to marine life, and data could then be used to further knowledge of and education about such areas, e.g., improving design of future reserves; broadening support for reducing underwater noise while limiting the impact on commercial activities.

Williams et al (2011; p. 4) provide a broader starting point for thinking about such criteria: “It is impossible to define MPA boundaries without first establishing management goals, i.e., knowing what we want the MPA to achieve. Hooker and Gerber (2004) reviewed marine mammal-focused MPAs and management objectives from two perspectives: (1) the potential for MPAs to protect marine predators from threats; and (2) the potential for marine predators to serve as ecological indicators or proxies to guide MPA siting and targeting. If the goal of management is to maintain biodiversity, then we would assign highest priority to areas that support the most species. If the goal is to prevent the extinction of species or populations of greatest conservation concern, then the priority would be to protect areas with habitat for those animals. If the particular vulnerability of a group of organisms to a given anthropogenic stressor, such as underwater noise, is the greatest concern, it may be most appropriate to adopt a spatio-temporal approach explicitly to manage the animals’ exposure to that stressor (Agardy et al., 2007; Lusseau and Higham, 2004). Examples of this latter approach involve mapping and managing the overlap of beaked whale occurrence with military sonar exercises, bowhead whale distribution with seismic surveys, areas of high-density occurrence of fin whales with shipping lanes (Williams and O’Hara, 2010), and feeding hotspots for southern resident killer whales with core areas used by whale-watching boats (Ashe et al., 2010). It is rare for animal behaviour to be incorporated into habitat-use models used for MPA planning (Ashe et al., 2010; Lusseau and Higham, 2004), but this need not be the case.”

Voluntary and Incentive Programs

Recommendation 7: Existing industry and port environmental incentive programs should be expanded to include underwater noise criteria.

Vessel speed restrictions are one way to reduce vessel noise, especially when these are targeted at individual vessels and their acoustic footprints, so that vessels may be required to travel at noise-optimizing speeds. Such an approach may also identify vessels producing excessive noise due to maintenance issues, e.g., propeller damage. Reducing vessels’ total noise emissions is a longer-term solution than spatial and temporal restrictions on noise-producing activities, and one that will have implications over a vessel’s entire operating area rather than just inside the boundaries of a slow-down zone. Both speed restrictions and vessel design and maintenance have roles to play in noise reduction. Quieter ships have already been designed and put into operation by navies and researchers. Thus, the technology is available, and would be particularly useful in efforts to restore acoustic habitat in noisy areas (e.g., ports, shipping lanes). Currently, guidelines and incentives are the most frequently used methods to reduce vessel noise at source. Voluntary guidelines to address underwater noise may not be sufficient to achieve noise reductions. It should also be noted that in regions undergoing dramatic increases in shipping traffic (as currently projected for BC’s North Coast, and the Greater Vancouver area), the reduction of noise output per vessel may not result in a net decrease of overall ship-related noise, and this must be addressed by setting cumulative noise exposure levels (see Recommendation 4).

- As part of the efforts by the voluntary industry association Green Marine to reduce the environmental footprint of marine shipping, an underwater noise pollution criterion should be added to its certification program.
- Port authorities should be encouraged to set both per vessel and regional noise targets, and to introduce incentive programs that reward quieter ships, e.g., by adding noise criteria to Port Metro Vancouver's EcoAction incentive program. These noise reductions could be brought about by measures targeting individual vessels and their specific noise footprints – vessels should ensure their ships undergo routine vessel maintenance, particularly in terms of propellers, anti-fouling, and reducing vibration in on board machinery. All of these will generally reduce underwater noise.
- Regional management solutions should be considered as part of the above port-based noise reduction programme: the successful 2007 Northwest Ports Clean Air Strategy (for the Ports of Seattle, Tacoma, and Vancouver) could potentially be expanded to cover underwater noise.

Education and Communication

Recommendation 8: Public and industry education programs should be developed about the impacts of underwater noise on marine life, and possible mitigation measures.

This workshop, and WWF's 2012 workshop on underwater noise, have attempted to promote ongoing dialogue and cross-sectoral relationships between managers, planners, industry, scientists, citizen researchers, and conservation and community groups on how best to incorporate managing underwater noise into best practices for the marine environment. This dialogue should be maintained.

- Plan one or more industry education workshops involving whale watchers, shippers, pile drivers, BC Ferries, tug boat operators and other producers of underwater noise.
- Develop a 'report card' system to inform ship owners about the source levels of their vessels.
- Design a recognisable mascot for the cause of underwater noise, such as a killer whale.
- Encourage small boat operators and whale watch vessels to shut off their depth sounders/fish finders when not in use, particularly in the presence of marine mammals, through expanded outreach and engagement on the 'Be Whale Wise' guidelines and the revised Marine Mammal Regulations.
- The revised Marine Mammal Regulations should be brought into force.

References

Stoneman, M. and H. Danielson, Fisheries and Oceans Canada, DFO Science and Policy on Ocean Noise in Heise, K. and H.M. Alidina (2012). Summary Report: Ocean Noise in Canada's Pacific Workshop, January 31 - February 1 2012, Vancouver, Canada. WWF-Canada.

Clark, C., D. Mann, P. Miller, D. Nowacek, and B. Southall, Comments on Arctic Ocean Draft Environmental Impact Statement at 2 (Feb. 28, 2012); see 40 C.F.R. § 1502.22.

Williams, R., K. Kaschner, E. Hoyt, R. Reeves, and E. Ashe. 2011. Mapping Large-scale Spatial Patterns in Cetacean Density: Preliminary work to inform systematic conservation planning and MPA network design in the northeastern Pacific. Whale and Dolphin Conservation Society, Chippenham, UK, 51 pp.

APPENDICES

Appendix 1: Agenda

Thursday June 6, 2013

Time	Focus	Speaker
8:00 – 9:00 am	**Continental breakfast and registration**	
9:00	Welcome, and framing the challenge	Linda Nowlan (WWF)
9:10	Introductions, housekeeping etc.	Lance Barrett-Lennard (Vancouver Aquarium)
	I- SETTING THE STAGE	
9:45	Sound 101: A backgrounder on underwater noise	Kathy Heise (Vancouver Aquarium)
10:40	**Break**	
	II- FRAMING THE ISSUES	
11:00	Current and proposed projects with underwater noise implications for the north and central coast.	Mike Ambach (WWF-PR)
11:20	The importance of underwater noise monitoring and mitigation in sensitive areas: the central coast as a case study.	Janie Wray (Cetacealab)
11:40	Q and A and general discussion	
12:00 pm	**Lunch**	
	III- TOOLS TO MANAGE NOISE: MPAS	
1:00	Keynote- Marine Mammal Protected Areas – Global experiences and ideas for Canada's Pacific with relevance to noise issues Followed by Panel Discussion Open Discussion	Erich Hoyt Panel: Doug Biffard (MOE) Erin Ashe (Ocean Initiatives) Jason Thompson (CHN) Andrew Wright (WWF)
2:30	**Break**	
	IV- OTHER TOOLS TO MANAGE NOISE	
2:50	EU Marine Strategy Framework Directive Descriptor 11: Underwater Noise	Lindy Weilgart (Dalhousie)
3:10	Lessons from the US in managing impacts of underwater noise on fish and marine mammals.	Michael Jasny (NRDC)
3:30	The marine mammal protection plan	Andrea Ahrens (Stantec/Northern Gateway)
3:50	Lessons learned from Port Metro Vancouver operations and development and the application of incentive programs for mitigation.	Darryl Desjardin (Port of Metro Vancouver)
4:10	Mechanisms for managing underwater noise impacts under the *Species at Risk Act* (SARA): Critical habitat protection measures.	Sheila Thornton (DFO-SARA).
4:30	Q and A and general discussion	All
5:15	**Adjourn**	

Friday June 7, 2013

Time	Activity	Speaker
8:00 am	**Continental breakfast**	
	V- CUMULATIVE IMPACT AND MITIGATION/COMPENSATION FRAMEWORKS	
9:00	An ecological risk assessment framework for Pacific Canada.	Cathryn Murray (WWF)
9:20	A national framework to incorporate and quantify risks of impacts on marine mammal populations from shipping noise or ship strikes, with a case study.	Jack Lawson (DFO Newfoundland)
9:50	A compensation and mitigation strategy for limiting the noise impacts of increased shipping on marine life.	Lance Barrett-Lennard (Vancouver Aquarium)
10:05	Discussion: Deciding on appropriate assessment frameworks for underwater noise management plans.	All
10:30	**Break**	
	VI- SHIPPING	
10:45	The Green Marine Program.	Jason Scherr (Port of Prince Rupert)
11:00	Underwater noise mitigation (for shipping and pile driving)	Lindy Weilgart (Dalhousie)
11:20	The role of the International Maritime Organization in developing standards for shipping.	Linda Nowlan (WWF)
11:35	Q and A and discussion with a focus on potential solutions applicable to BC.	Facilitated by Richard Holt (Environment Canada)
12:00 pm	**Lunch**	
	VII- BREAKOUT GROUPS: PUTTING THE WORK INTO THE WORKSHOP!	
1:00 pm	Acoustic reserves as a strategy to reduce the impacts of underwater noise: where should they be located? Are they appropriate for the Douglas Channel/ Caamaño Sound area?	
	Noise standards for BC and Canada: what is appropriate? What role is there for incentivizing reduction or quieting technologies?	
	Marine plan implementation. Given current processes, how should PNCIMA, MaPP, and the BC government incorporate underwater noise considerations in development plans? What would be the priorities?	
	What could we achieve within the next five years locally/ within BC?	
	Break	
3:00	Reporting out of breakout groups (15 min/group)	
4:00	Final wrap up and recommendations	Lance Barrett-Lennard
4:30	Adjourn	

Appendix 2: Workshop Participants

*indicates participants who prepared presentations that are summarized in this report

First Name	Last Name	Affiliation
Selina	Agbayani	WWF-Canada
Andrea	Ahrens*	Stantec/ Northern Gateway
Mike	Ambach*	WWF-Canada
Erin	Ashe	University of St. Andrews and Oceans Initiative
Lance	Barrett-Lennard*	Vancouver Aquarium/Dept. of Zoology, University of British Columbia (UBC)
Janine	Beckett	Stantec
Doug	Biffard	BC Parks, Ministry of the Environment
Louise	Blight	WWF-Canada
Carrie	Brown	Port of Metro Vancouver
Paul	Cottrell	Fisheries and Oceans Canada (DFO) Vancouver
Dolf	de Jong	Vancouver Aquarium
Darryl	Desjardin*	Port of Metro Vancouver
Peter	Ewins	WWF-Canada
John	Ford	DFO Science
Marianne	Gilbert	Hemmera
Michelle	Gilders	British Gas Group
Sydney	Gudmundson	WWF-Canada
Anna	Hall	AECOM
Kathy	Heise*	Vancouver Aquarium
Richard	Holt	Environment Canada
Erich	Hoyt*	Whale and Dolphin Conservation Society
Michael	Jasny*	Natural Resources Defense Council
Sabine	Jessen	Canadian Parks and Wilderness Society
Jack	Lawson*	DFO St. Johns, Newfoundland
Lynn	Lee	Haida Gwaii Marine Advisory Committee
Karen	Leslie	DFO Oceans
Rebecca	Martone	Centre for Oceans Solutions, Stanford University
Megan	McCann	Seaspan International
Cathryn	Murray*	WWF-Canada
Linda	Nowlan*	WWF-Canada
Susan	Pinkus	Ecojustice
Bruce	Reid	DFO Oceans
Max	Ritts	Dept. of Geography, UBC
Jason	Scherr*	Prince Rupert Port Authority
Jo	Smith	Marine Planning Partnership for the North Pacific Coast
Jason	Thompson	Council of the Haida Nation
Sheila	Thornton*	DFO Vancouver

First Name	Last Name	Affiliation
Dom	Tollit	SMRU Canada
Karen	Topelko	BC Parks, Ministry of the Environment
Laani	Uunila	Parks Canada
Lindy	Weilgart*	Dalhousie University
Tonya	Wimmer	WWF-Canada
Janie	Wray*	Cetacealab
Andrew	Wright	WWF-International
Kim	Wright	Living Oceans Society

Breaching killer whale near Cetacealab. c. forwhales.org

Appendix 3: A Primer on Underwater Sound and Noise

A Primer on Underwater Sound and Noise: Backgrounder for WWF's 2013 Workshop on Finding Management Solutions for Underwater Noise in Canada's Pacific.

This background document is intended for those who know relatively little about sound, the differences between sound in water relative to sound in air, and some of the more common sources of underwater man-made sounds (anthropogenic noise). It is not an exhaustive overview, but I hope that it will provide sufficient information to will give the reader some familiarity with the topic, and direct the reader to more detailed references that will be useful in the course of their own work.

Many marine animals use sound in much the way that terrestrial animals use light- to detect predators and/or prey, to communicate, and to navigate- it is their primary underwater sensory modality. This shouldn't be surprising to us, since in water sound travels much further than light does. Yet as the visual creatures we are, it is only within the last 10 years or so that concerns around the introduction of man-made sound (anthropogenic noise) into the oceans has moved well beyond the domain of a specialized group of researchers into the broader public domain. With this increased awareness has come motivation to understand and mitigate the impact of underwater noise on marine life.

The ears of all terrestrial vertebrates, including humans, are functionally similar to those of marine vertebrates (Fay and Popper, 2000). In humans, hair cells in the inner ear that are sensitive to sounds that we hear can be damaged or destroyed by a number of causes, including aging processes, prolonged or intense exposure to noise, and chemical contaminants etc. Similar results have been found in other species ranging from fish to reptiles to birds (Rubel et al., 2013). Human noise exposure standards in the workplace have been developed in many countries around the world and significant progress has been made within the last decade to develop similar criteria for marine mammals (Southall et al., 2007).

What is sound?

A sound is produced by the mechanical vibration of particles in the medium (such as the ocean) through which the sound travels. As the particles of the medium vibrate (particle motion), their density increases and decreases (compression and rarefaction). These local oscillations result in disturbances that propagate, generating sound pressure waves. These waves can travel through air, water and rock, as well as other substrates, the speed of which depends on the medium (Table A1). While the ears of mammals primarily sense the very small pressure changes due to sound waves, the lateral lines and ears of fish are also sensitive to particle motion which occurs close to the source of the sound. For the purpose of this workshop, we will not be addressing particle motion in significant detail, and will focus on pressure waves.

Table A1. The speed of sound (m/s) in various media, from JASCO Applied Sciences (2009).

Medium	Speed of sound in m/s
Air at 20°C	343
Salt water at 25°C	1532
Sand	800-2,200
Clay	1,000-2,500
Sandstone	1,400-4,300
Granite	5,500-5,900
Limestone	5,900-6,100

How do we describe sound?

Laypeople typically describe a sound by its loudness, and sometimes its pitch. The criteria that determine these characteristics are basically the sound wave's amplitude (loudness), frequency (pitch), and duration. Waveforms are used to show time vs. amplitude (Figures A1-2), and spectrograms show time vs frequency, much like a musical score (Figure A3). Continuous sounds such as boat noise are described as chronic or non-pulsed whereas sounds that are of short duration, such as an explosion, or of repeated short durations, such as pile driving or airgun firing, are pulsed (or acute, intermittent or transient) sources of noise. In the Atlantic Ocean, airgun firing is such a predominant sound that it is often described as chronic because it is ever-present, but the original signal is a pulsed sound. Sounds such as killer whale whistles or military sonars are generally described as narrowband, whereas sounds that encompass a range of frequencies, such as shipping noise or pile driving, are broadband (Figure A3).

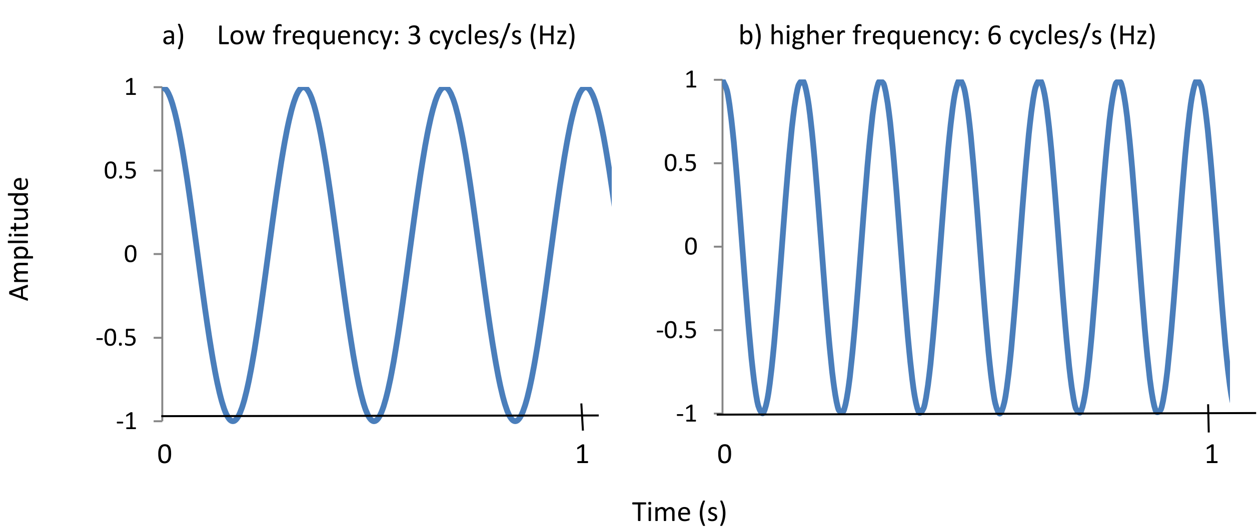

Figure A1. Waveforms of a low (a) and higher (b) frequency continuous sound wave.

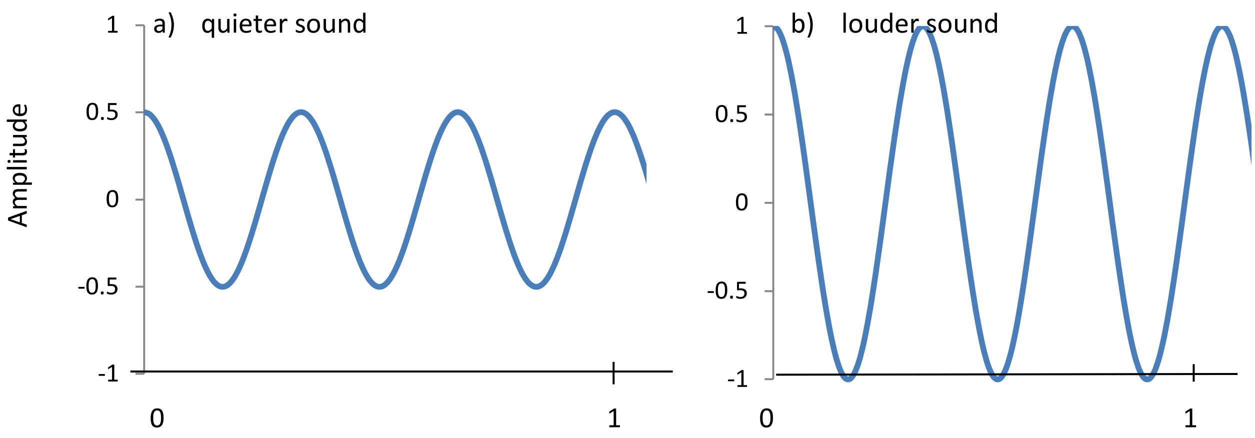

Figure A2. Waveforms of a quiet (a) and a louder (b) continuous sound wave of the same frequency.

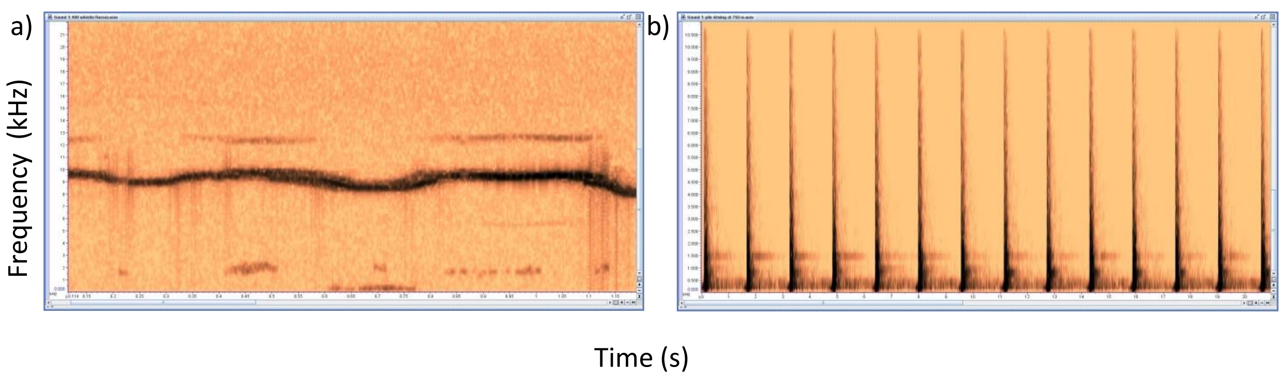

Figure A3. Spectograms of a) the continuous and narrowband sound of a killer whale whistle, and b) the pulsed and broadband sound of pile driving.

At age 10, the typical human hearing range is between 20 Hz and 20,000 Hz (20 kHz). However, we do not hear equally well at all of the frequencies in between. Hearing tests, or audiograms, have shown that human peak hearing frequencies range between 2-4 kHz, and fall off at frequencies above and below this range. You can make your own audiogram at www.myhearingtest.net Audiograms have been undertaken for a number of marine animals, and have been used as a tool to determine noise exposure criteria. In the US, for the purposes of developing noise exposure criteria, marine mammals have been divided into functional groups depending on their best hearing sensitivity (Southall et al., 2007).

Table A2. The five functional hearing groups for noise exposure criteria based on Southall et al. (2007).

Group	Examples
Low-frequency cetaceans	baleen whales- e.g., gray, fin, and blue whales
Mid-frequency cetaceans	toothed whales and dolphins – e.g., sperm, killer and beluga whales, Pacific white-sided dolphins
High- frequency cetaceans	porpoises – e.g., Dall's and harbour porpoises
Pinnipeds in air	all seals, sea lions and fur seals e.g., Harbour seals, Steller sea lions
Pinnipeds in water	all seals, sea lions and fur seals e.g., Harbour seals, Steller sea lions

It is critically important to appreciate that the lower the frequency of the sound, the further the sound will travel. In water, a 100 Hz signal can travel over 1000 km with relatively little loss of sound energy. Most of the energy in shipping noise, and in baleen whale communication signals, lies in frequencies below 1000 Hz. In many approaches to analysing sounds, the energy is measured within different frequency bands. The bandwidth used most often in bioacoustics is 1/3 of an octave, where an octave represents a doubling of frequency (Table A3). The European Union has chosen the 63 Hz and 125 Hz 1/3 octave bands as the focus of their long term underwater noise monitoring program.

How do we describe sounds quantitatively?

There are a number of units that are used to describe sound, but unlike volume or length measurements that have absolute values, measures of sounds are relative. The decibel (dB) is now the most commonly used unit when considering the biological impacts of sound, and it is simply a unit in a logarithmic scale that describes sound intensity level or pressure level relative to a fixed reference intensity or pressure. For every 3 dB increase, the sound energy doubles. In air, the reference intensity is 20 micropascals (µPa) or .0002 microbars, which is considered to be the general lower limit of audibility to the human ear. However, the reference intensity for sound in water is 1 micropascal (µPa). Therefore sound pressure levels in air are not the same as sound pressure levels in water. When evaluating sound measurements, the reference intensity should always be clearly stated. In water, the reference intensity is typically expressed as dB re 1 µPa @ 1 m.

Table A3. Octave and 1/3 octave band centre frequencies and band limits. The lower the frequency, the further the sound will travel, in both air and water.

Frequency (Hz))					
Octave Band			1/3 Octave Band		
Lower Band Limit (Hz)	Centre Frequency (Hz)	Upper Band (Hz)	Lower Band Limit (Hz)	Centre Frequency (Hz)	Upper Band (Hz)
11	16	22	14.1	16	17.8
			17.8	20	22.4
			22.4	25	28.2
22	31.5	44	28.2	31.5	35.5
			35.5	40	44.7
			44.7	50	56.2
44	63	88	56.2	63*	70.8
			70.8	80	89.1
			89.1	100	112
88	125	177	112	125*	141
			141	160	178
			178	200	224
177	250	355	224	250	282
			282	315	355
			355	400	447
710	1000	1420	891	1000	1122
			1122	1250	1413
			1413	1600	1778
1420	2000	2840	1778	2000	2239
			2239	2500	2818
			2818	3150	3548
1420	2000	2840	1778	2000	2239
			2239	2500	2818
			2818	3150	3548
2840	4000	5680	3548	4000	4467
			4467	5000	5623
			5623	6300	7079
5680	8000	11360	7079	8000	8913
			8913	10000	11220
			11220	12500	14130
11360	16000	22720	14130	16000	17780
			17780	20000	22390

* The EU Marine Strategy Framework Directive on Noise[13] has selected the 63 and 125 Hz 1/3 octave bands as the focus of their long term underwater noise monitoring program.

[13] http://ec.europa.eu/environment/marine/pdf/MSFD_reportTSG_Noise.pdf

There are a number of ways to describe sound pressure levels (SPL), but there is still disagreement amongst acousticians on what the best metrics are, and there are no internationally agreed upon standards to report SPLs. Depending on how the pressure or sound energy is calculated or measured, the numerical value associated with a sound can vary significantly (by 20 dB or more). Figure A4 shows a waveform and 3 different ways of describing the energy of the sound pressure wave of a continuous sound (root mean square [rms], peak amplitude (or 0-peak), and peak to peak amplitude). Rms measures are almost always lower than peak to peak or peak amplitude measures, because they are typically (but not always) averaged over one second. The length of time that passes before a sound reaches its peak amplitude is the rise time. The shorter the rise time, particularly for high amplitude sounds, the greater the concern for potential biological impacts. Table A5 shows how rms pressures can be calculated for Figure A4. Sound pressures reported for short duration pulsed sounds will have the same zero-peak and peak-peak amplitude as a continuous sound, but the rms value will be lower than for a continuous sound (Figure A5). Thus rms values are not ideal for describing high energy pulsed sounds, since they don't appropriately characterize the sound (Madsen, 2005).

Table A4. Some examples of underwater sound pressure levels in different units, modified from JASCO Applied Sciences (2009).

Sound source	dB re 1 μPa	Bar	Pascal (Pa)
Peak pressure of one GI 45 in^3 airgun @ 1 m	228	2.5	2.5 x 10^5
Peak pressure of a sperm whale click	223	1.4	1.4 x 10^5
Peak pressure of pile driving (75 cm diameter, 13 mm wall thickness, 180 kJ hammer @14 m)	207	0.2	20,000
Source level (rms) of a zodiac with twin 175 hp outboards travelling at 55 km/hr	169	2.8m	280
Source level (rms) of a zodiac with twin 175 hp outboards travelling at 10 km/hr	147	0.2m	20
Source level of a killer whale whistle	140	0.1m	10
Snapping shrimp power spectrum density level at 4 kHz	72	40n	4m

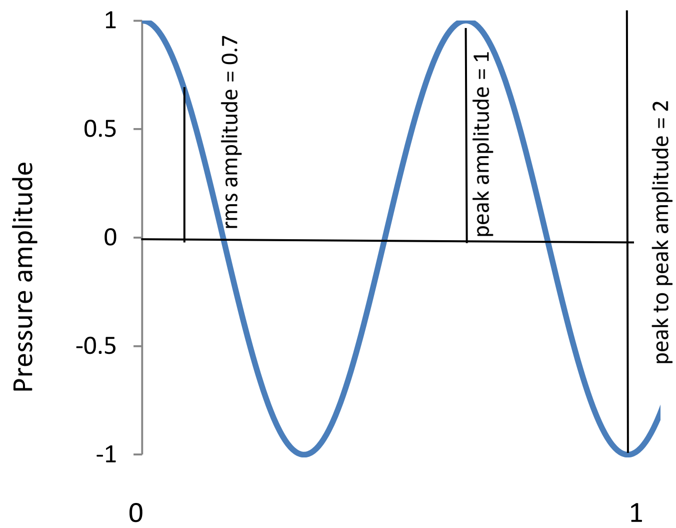

Figure A4. A waveform showing several ways of expressing the amplitude of a continuous sound. The root mean square (rms) amplitude is 0.8, the peak amplitude is 1 and the peak to peak amplitude is 2.

Table A5. Sample calculation for the rms pressure of the sound wave in Figure A4.

Steps for calculating the rms pressure in Figure A4	Sample calculation
Measured pressure along the wave	1,0,-1,0,1,0,-1
Square the measured pressures	1,0,1,0,1,0,1
Average the squared pressures	(1+0+1+0+1+0+1)/7= 0.57
Take the square root of the averaged sound pressures to calculate the rms. This is the sound pressure averaged over one second.	=0.76

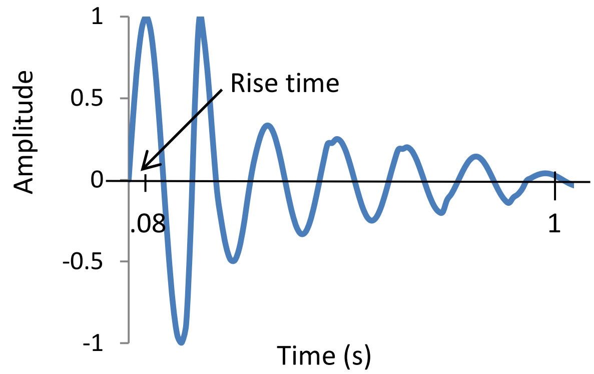

Figure A5. A waveform of a hypothetical pulsed sound. The rms is ~0.35, the peak amplitude is 1 and the peak to peak amplitude is 2. The rise time for the pulse to reach peak amplitude is ~0.08 s.

For simplicity, in the previous figures I have ignored the very basic rule that should be followed when evaluating sounds: the units and their reference pressure should be clearly stated. The units for underwater sound pressure levels (SPL) are dB re 1 μPa^2 although they are often presented as dB re 1 μPa (Ainslie 2010). Sound pressure levels are commonly expressed as peak or zero to peak sound pressures (SPL_{pk}), root mean square (rms) sound pressures (SPL_{rms}), or peak to peak sound pressures (SPL_{p-p} or SPL_{pk-pk}) depending on the source and duration of the sound. If SPL_{rms} is used to describe a pulsed sound, the duration of the pulse is the time between 5 and 95% of the total sound energy of the signal.

Unlike sound pressure levels, sound exposure levels (SEL) measure the total energy of a signal over time. In water, the sound exposure units are dB re 1 $\mu Pa^2 \cdot s$ and can be used to compare sounds that are continuous, single, or multiple pulses, and can also be used to describe the cumulative exposure of a sound over the duration of a specified time period. SELs are often used to compare transient sound events that have different durations and pressures. They are also reported as energy flux densities.

It is also very important to note whether the sound energy is reported at the source, or is a received level. Source levels are most commonly described as occurring at 1 m from the source, yet for sources over a few cm in size, this is technically impossible to measure, because the sound is actually produced over a distance greater than 1 m. The noise produced by a 200 m ship occurs over the length of the ship, and similarly in a multi-airgun array used in a seismic survey, there are multiple individual sources of noise (each airgun). Source levels are therefore mathematically back-calculated from measures of received sound levels at a distance from the source, which are then modeled to compute the pressure at 1 m range, as if the real source was collapsed into a point-source.

What is a sound and what is noise?

The answer is qualified- it depends on the perspective of the listener. Noise is unwanted sound. It can include ambient background noise, and local interfering sounds. There are many naturally occurring sounds in the ocean, and they can be quite loud. These range from abiotic sources (e.g. rainfall, wind and wave noise, thunder and earthquakes etc.) to the sounds of marine animals (made by fish, invertebrates and marine mammals). The reader should appreciate that the marine environment is not a naturally quiet place. However, for the purpose of this backgrounder, we will consider 'noise' to be anthropogenic (man-made) 'sounds' that may potentially impact marine animals.

What are some of the sources of anthropogenic noise in the marine environment?

On the BC coast, the most common source of anthropogenic underwater noise is vessel traffic, and finding solutions to manage it is the main focus of this workshop. Source levels of a selection of anthropogenic noise sources are listed in Table A6. In the open Pacific, ambient noise levels have increased ~2.5- 3 dB per decade during the last 40 years, particularly at frequencies below 300 Hz, and much of this is attributed to increased commercial shipping (McDonald et al., 2006; Spence et al., 2007; Chapman and Price, 2011; among others). Recall that each 3 dB increase is effectively a doubling of the amount of sound energy produced, because dB measurements are based on a logarithmic scale. In inshore waters, characterizing the contribution of vessels to the ambient noise environment is more variable, as some areas have relatively few boats, whereas others, such as the vessel traffic approaches to major harbours, can be incredibly noisy (see Erbe et al., 2012a, b). As shipping traffic grows in BC, we can expect the overall ambient noise levels to increase, unless there is a mandate to reduce underwater noise levels.

Table A6. A selective list of source levels of anthropogenic noise sources in the marine environment, modified from Hildebrand (2009).

Sound source	**Source level (dB re 1UPa @ 1m)**	**Duration (s)**
Short duration sounds		
Ship shock trial (4536kg explosive)	304	2
Torpedo MK-48 (44 Kg explosive)	289	0.1
Air-gun array	260	0.03*
Pile driving 1000 kJ hammer	237	0.05*
US Navy 53C ASW sonar	235	2*
Multi-beam shallow water sonar	232	0.002*
Seal bomb (2.3 g explosive)	205	0.03
Continuous sounds		
Cargo vessel 173 m @ 16 knots	192	Continuous
Acoustic telemetry	190	Continuous
Outboard powered small boat @20 knots	160	Continuous
Operating wind turbine	151	Continuous

*Short duration but repetitive pulses

Noise comes from a variety of sources on a vessel, but the largest contributor is cavitation of the ship's propeller. Generally speaking, the faster a vessel travels, the greater the cavitation noise, especially at speeds in excess of 8 to 12 knots (Spence et al., 2007; McKenna et al. 2013). However, some vessels have variable pitched or controllable pitched propellers, and shafts that are rotating continuously (e.g. the new BC Ferries), and these vessels can generate more noise at slower speeds than when operating at full speed (Renilson Marine Consulting, 2009). Other sources of noise on a vessel include bow thrusters, machinery noise (esp. the propulsion system), pumps, and propeller singing[14]. Manoeuvring, loading, hull design and operator's behaviour also affect the amount of noise each vessel generates. Poor vessel maintenance can increase the noise of a vessel: McKenna et al. (2013) found that 10 % of all container ships transiting Santa Barbara Channel produced additional narrowband high frequency tones: these are likely associated with propeller damage and/or onboard machinery requiring maintenance. Shipping noise is broadband and can extend to greater than 100 kHz, but it is usually the lower frequencies that are of concern because they travel furthest. Although often not considered in describing large scale changes to the ambient noise environment in an area, small to medium size vessels, including coastal freighters, tugs, fishing vessels, pleasure craft, and whale-watching vessels, also contribute to the underwater soundscape.

Table A7. Source spectral densities for different types of commercial vessels underway, for several frequencies (from NRC 2003).

			Source spectral density (dB re 1 µPa^2/Hz @ 1 m)				
Ship Type	Length (m)	Speed (m/s)	10 Hz	25 Hz	50 Hz	100 Hz	300 Hz
Supertanker	244-355	7.7-11.3	185	189	185	175	157
Large tanker	155-214	7.7-9.3	175	179	176	166	149
Tanker	122-153	6.2-8.2	167	171	169	159	143
Merchant	84-122	5.1-7.7	161	165	163	154	137
Fishing	15-46	3.6-5.1	143	143	141	132	117

Noise associated with construction and industrial activities is also a significant concern. Harbours can be particularly noisy, not just due to vessel traffic, but because of pile driving, dredging, and shipyard activities, amongst other sources. An additional and possibly significant but poorly documented source of noise in harbours is nearshore land based machinery noise that propagates through the substrate into the marine environment (NRC, 2003).

Pile driving noise is of concern both in air and in water because the sound energy of each pulse has a very fast rise time and high peak pressure, and the strikes are repeated for up to thousands of times per day. Driven piles are used to support structures such as docks, bridges, wind turbines and navigational aids. The piles are driven into the substrate using impact hammers, or alternatively, vibratory hammers

[14] Propeller singing is audible to the human ear and typically ranges from 10-1,200 Hz but up to 12 kHz, and is due to the vortices associated with the trailing edge of the propeller as it turns. It is often mediated by notching the trailing edge of the propeller.

or press-in piles. The amount of noise produced by driving piles depends on the diameter of the pile, the hammer size, the material the pile is constructed of, the characteristics of the substrate, etc. In addition, the pulse that propagates down the pile can couple with the substrate and cause pressure waves to propagate through the sediment (recalling that sound travels through rock even more readily than through water, Table A1). Thus it is possible that a distance from the pile, there can be localized areas of very high or very low sound pressure and acoustic particle motion than at distances closer to the pile. See Popper and Hastings (2009) for a more detailed discussion of this topic. Table A8 shows sound pressure levels reported for different types of piles and hammers, and illustrates how the range of reported values varies depending on which metrics are used.

Table A8. Sound pressures from marine pile driving expressed in different metrics, from Rodkin and Reyff (2007).

Pile type (diameter)/ Hammer type	Distance from pile (m)	Peak sound pressure (dB re 1 μPa)	RMS sound pressure (db re 1 μPa)	Sound exposure level (dB re 1 $\mu Pa^2 \cdot s$)
Timber (0.3 m)/drop	10	177	165	157
Steel shell (0.3m)/drop	10	177	165	152
Concrete (0.6 m)/impact	10	183	171	160
CISS (0.3m)/impact	10	190	180	165
CISS (2.5m)/impact	25	212	197	188

(CISS = Cast in steel shell piles = concrete piles within a steel shell)

In the Atlantic Ocean, industrial activity related to offshore oil and gas production is a very significant source of underwater noise. Airguns used for seismic surveys generate high-amplitude broadband pulsed sounds that have been a source of concern for decades, because of their potential impacts on marine life. Much of the sound energy they generate is at low frequencies, which can be detected 4,000 km away (Nieukirk et al., 2012). At greater distances, the duration of the pulse increases (due to multi-path propagation), increasing the background noise level. However, airguns are rarely used in British Columbia, except for research purposes. Other sources of underwater noise include vessel sonars, and military activities (including low, mid and high frequency sonars, torpedoes, ship-shock trials etc.). New and emerging technologies (autonomous underwater vehicles, modems etc.) also add noise to the underwater environment.

Why is underwater noise a concern for marine life?

Anthropogenic noise has the potential to interfere with the ability of marine animals to carry out vital life processes, such as foraging, reproduction, predator avoidance, communication and navigation. Noise can impact animals by causing behavioural changes, although these are often subject to interpretation and can depend on the age, sex, health, context and prior experience of the animal. Noise can mask important biologically important sounds such as communication and echolocation signals and the ability of animals to passively listen for predators, prey or environmental cues (e.g. beaches, high surf areas). High energy sound can cause physiological responses, including changes in stress hormone levels, tissue resonance, and acoustic trauma, as well as temporary and/or permanent threshold shifts in hearing ability. Marine animals that lose their ability to hear the sound of approaching predators or the ability to detect their prey acoustically are at greater risk of mortality. Ultimately, in certain conditions high-energy noise can result in direct mortality.

It is not within the scope of this backgrounder to provide a full review of the potential impacts of underwater noise on marine life, and there are many references that address this topic in significant detail. A number have been published within the last 10 years, almost all of which call for further research (Table A9). This list is not comprehensive, but rather a sampling of the literature. The complete reference is provided in the Relevant Literature section of this backgrounder.

Table A9. A selection of recent literature on the effects of underwater noise on marine life. Complete details of each reference are provided in the Relevant Literature section below. This list is not comprehensive.

Author (date)	**Focus of paper**
NRC (2003)	A synthesis of what is known about marine mammals and noise
IACMST (2006)	A summary report on the effects of underwater noise on marine life from a UK perspective
Nowacek et al. (2007)	A review of behavioural response of marine mammals to noise
Southall et al. (2007)	A review of the impacts of noise on marine mammals with criteria for noise exposure standards for the US
Weilgart (2007)	A synthesis of the impacts of noise on cetaceans
Wright and Highfill (2007)	A collection of papers on the effects of noise on marine life
Wright (2008)	A review of the impacts of shipping noise on marine mammals
Boyd et al. (2008)	A draft research strategy to assess the effects of noise on marine mammals
Hawkins et al. (2008)	A collection of papers presented at the 2007 'Effects of noise on aquatic life' conference in Nyborg, Denmark
OSPAR (2009)	A synthesis of the impacts of underwater noise on marine life
Popper and Hastings (2009)	A synthesis of the effects of anthropogenic noise on fish
Slabbekoorn et al. (2010)	A synthesis of the consequences of increasing ambient noise levels for fish
Normandeau and associates (2012)	A synthesis of the effects of noise on fish and invertebrates
Popper and Hawkins (2012)	A collection of papers presented at the 2010 'Effects of noise on aquatic life' conference in Cork, Ireland

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Appendix 4: Overview of Ocean Noise Regulation in Canada

Overview of Ocean Noise Regulation in Canada

Backgrounder for WWF Workshop, June 6-7, 2013

Anthropogenic sound in the marine environment is an issue that is likely to increase in significance over the next few decades, which could have both short- and long-term negative consequences for marine animals. The uncontrolled introduction of increasing noise is likely to add significant further stress to already-stressed oceanic biota. Protecting marine life from this growing threat will require more effective control of the activities producing sound which depends on a combination of greater understanding of the impacts and also increased awareness of the issue by decision makers both nationally and regionally to implement adequate regulatory and management measures.

Convention on Biological Diversity. Scientific Synthesis on the Impacts of Underwater Noise on Marine and Coastal Biodiversity and Habitats. CBD/CBD/SBSTTA/16/INF/12.Montreal, Canada. 2012

This Backgrounder provides an overview of federal ocean noise regulation in Canada, with a primary focus on shipping noise.

Ocean noise is a complex environmental threat. It is difficult to regulate as unlike other pollutants, it is invisible and odourless. The harm it can cause is highly variable depending on a number of environmental factors, the susceptibility of species to harm, and the qualities of the noise.

The two main ways to control underwater noise are to cut down on the noise caused by human activity, such as making ships quieter, and to keep noisy activities away from vulnerable species altogether or at certain times or in certain places, known as spatio-temporal restrictions.[i]

The focus of this Backgrounder is on national regulation, though underwater noise is best dealt with by international regulations, as both oceans and noise recognize no borders. Two prominent examples are highlighted below from many international and regional legal instruments that could apply to regulate underwater noise.

Internationally, there are no comprehensive global rules on underwater noise. The International Maritime Organization (IMO) the UN agency that governs the world's maritime shipping, has been developing draft *Guidelines for Minimizing Underwater Noise from Commercial Ships,* for the past five years. [ii] As the name implies, these IMO Guidelines are not binding on Canada or any IMO Member States. International treaties or Conventions developed by the IMO apply in Canada only when the obligations are incorporated into Canadian legislation.

Regionally, the European Union's Marine Strategy Framework Directive (MSFD) is the most developed legal response to ocean noise to date. [iii] The MSFD commits the EU Member States to take the necessary measures to achieve or maintain good environmental status within the marine environment by the year 2020 at the latest. Good Environmental Status is defined by eleven high level descriptors including biological diversity, fish population, eutrophication, contaminants, and litter. Descriptor number 11 states that "...Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment."

Canadian Federal Laws

There are currently no comprehensive federal laws or standards to regulate ocean noise in Canada, though a number of laws designed for other purposes could be used to regulate ocean noise impacts. Canada has specific guidelines for mitigating ocean noise impacts produced by underwater seismic surveys and sonar.

The sections below discuss regulating underwater noise first by activity, and second, by species and habitat.

Regulating Activities that Produce Harmful Underwater Noise

Shipping

Reducing the overall noise output from marine vessels is likely to have demonstrable positive outcomes for acoustic communication, navigation, foraging efficiency, predator avoidance capabilities and noise induced stress.[iv]

Noise from shipping is pervasive throughout the marine environment, and ambient or background noise levels have been rising in recent decades due to increases in shipping traffic and tonnage Maritime shipping constitutes a major source of low-frequency noise in the particularly in the Northern Hemisphere where the majority of ship traffic occurs. Underwater ship noise is an incidental by-product from standard ship operations, mainly from propeller cavitation. Methods to control ship noise include construction, design, equipment and manning (CDEM) standards such as ship quieting technology, routeing measures; (IMO Areas to Be Avoided) and operational measures; e.g. speed limits are all techniques that can be used to reduce underwater noise from ships.

The *Canada Shipping Act* is the main law that governs marine transportation and applies to Canadian vessels operating in all waters and to all foreign vessels operating in Canadian waters (from canoes and kayaks to cruise ships and tankers). [v] The law gives the government broad powers to "protect the marine environment from damage due to navigation and shipping activities."[vi] Canadian vessels could be required, for example, to use low noise-producing propellers and engines.[vii] In this way, vessel emission of ocean noise could be reduced, and the *Canada Shipping Act's* objective of protecting the marine environment from damage due to shipping activities would be furthered. Another section of the law allows Cabinet to make regulations to control noise emissions from pleasure craft engines.[viii]

Ports also have legal powers to control ship activities under the *Canada Marine Act* and impose "green shipping" requirements above and beyond federal shipping law requirements on ships that enter their waters subject to a few limitations.[ix].

Seismic Surveys

Seismic sound is produced by seismic surveys, which use air guns, or “air source arrays,” to gather information about geological structures beneath the surface of the earth. Seismic sampling uses sound waves to “see” into the Earth’s rocks. Seismic surveys are typically conducted in marine environments for oil and gas or mining exploration or scientific research purposes. This is one activity for which specific guidelines exist. The Department of Fisheries and Oceans’ (DFO’s) Statement *of Canadian Practice: Mitigation of Seismic Sound in the Marine Environment (Seismic Statement)* applies unless otherwise noted, to all seismic activities that use an air source array.[x]

Military Sonar and other Military Sound Producing Activities

The Department of National Defence (DND) has a Maritime Command Order establishing Marine *Mammal Mitigation Procedures* (MMMP) to “give direction and implement standards of practice when conducting Exercises-Operations that involve the use of Underwater Sound Generating Systems that may pose a pervasive disturbance, harassment or injury risk to marine mammals,” and includes guidance for non-sonar activities such as weapons firings when in the area of Maritime Marine Mammals.”[xi] The MMMP standards of practice which include mitigation avoidance zones, pre-exercise planning, pre-exercise start procedures, ramp-up procedures, exercise operating procedures are not legally binding.

Underwater Construction

Canada’s approach to mitigating ocean noise produced by underwater construction activities such as dredging and pile driving in the Pacific Region are similar to those for seismic air guns.[xii] Merasures to mitigate construction noise will typically be applied when an underwater construction project may disturb a marine species, or when the project undergoes an environmental assessment.

Regulating Projects through Environmental Assessments

Proposed projects with the potential for negative environmental impacts may undergo environmental assessment.

The *Canadian Environmental Assessment Act;*[xiii] *(CEAA)* is the principal piece of federal legislation by which the environmental effects of human undertakings are assessed. CEAA seeks to avoid “significant adverse environmental effects” that will likely arise if a project is carried out. Therefore, if the emission of ocean noise can be shown to produce adverse environmental effects, projects that will emit ocean noise may be required to manage or avoid the negative impacts of doing so if they undergo an environmental assessment. In this way, *CEAA* enables ocean noise regulation. The specific mitigation procedures that an ocean noise emitting project will be required to implement to avoid adverse environmental effects will be approved and will be taken account of in a certificate issued for the project. Alternatively, if a project cannot mitigate adverse environmental effects of ocean noise, it can be denied approval.

Ocean noise has been assessed as an environmental effect of projects conducted in marine environments that have undergone an environmental assessment under *CEAA.*

If the impacts cannot be mitigated, approval may be denied or postponed. An example of an EA in the Pacific that resulted in a project not going ahead is the Batholiths Project which was postponed due to uncertain potential effects from airguns used in seismic technology on SARA listed marine mammals.[xiv]

Regulators can impose conditions on project approval to mitigate noise impacts. An example of a project currently undergoing an environmental assessment and National Energy Board hearing, combined into a Joint Review Panel, is the Enbridge Northern Gateway project (the "Project") which would add 220 tankers, or 440 transits, in Douglas Channel each year. Enbridge proposes to use a Marine Mammal Protection Plan) with a variety of mitigation measures to manage underwater noise, such as, e.g., vessel speed restrictions, construction and decommissioning support vessels, and low noise propulsion. DFO Science stated in its review of the Project that: "It is not possible at this time for DFO Science to determine acceptable noise thresholds in the CCAA in the absence of additional modeling and in-field measurements." [xv]Finally, the Joint Review Panel issued a total of 199 conditions should the Project be approved, a number related to underwater noise impacts. These potential conditions could form part of any approval of the Project, should it be approved. Enbridge Northern Gateway will not own or operate the tankers that call at the marine terminal.

Laws to Protect Species and Habitats from Harmful Levels of Ocean Noise

According to experts, mitigation and management of anthropogenic noise through the use of patio-temporal restrictions of activities , or separating noise events and activities from biologically important areas or concentrations of cetaceans is the most practical and straightforward approach to reduce effects on marine animals.[xvi]

There are examples where these restrictions have been used in other countries. Spain imposed a moratorium on the use of sonar around the Canary Islands due to beaked whale stranding episodes. Oil and gas exploration is not allowed and seasonal restrictions exist for vessel traffic in the marine mammal protection zone in the Great Australian Bight.

Species Laws

Underwater noise reduction or minimization at the national level in North America has tended to be through species protection laws, such as the US *Marine Mammal Protection Act*.

In Canada, if there is proof that ocean noise harms or disturbs species listed under Schedule 1 of the *Species at Risk Act (SARA)* [xvii] , the federal endangered species law, then this Act provides some responses. The Act prohibits, provided certain criteria are met, the destruction of any part of the critical habitat of "any listed endangered species or of any listed threatened species — or of any listed extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada." The case *David Suzuki Foundation v. Canada (Department of Fisheries and Oceans)*[xviii] confirmed that the acoustic quality of killer whale critical habitat was an aspect of critical habitat that must be legally protected.

The federal *Fisheries Act* [xix] could be used to regulate ocean noise through prohibitions on destroying fish other than by fishing and through habitat protection provisions (though the impact of new regulations under an amended *Fisheries Act* are still uncertain). The definition of "fish" in the Act includes marine animals. The *Fisheries Act* defines "fish habitat" broadly as the "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes." Based on these definitions, the *Fisheries Act* should apply to all marine species and their habitat and if ocean noise could be shown to destroy the species or harmfully alter, disrupt or destroy its habitat, these sections enable ocean noise regulation.

The *Marine Mammal Regulations*, enacted under the *Fisheries Act*, prohibit the "disturbance" of marine mammals by any means other than fishing.[xx] The "Be Whale Wise Guidelines" have also been developed to minimize the impact of whale watching boats on whales[xxi]. Non-compliance with may lead to prosecution.

Protected Areas Laws

Marine protected areas may provide the strongest form of protection from harmful noise impacts in the ocean. Several laws govern marine protected areas in Canada: under the *Oceans Act;*[xxii] Cabinet can designate MPAs, prescribe zones in the MPAs; and prohibit activities within MPAs. Assuming ocean noise can be shown to negatively impact the health of marine environments, therefore contravening the purpose of MPAs which is the conservation and protection of marine environments, then activities which produce ocean noise can be prohibited or regulated in MPAs.

Examples in Canada of federal MPAs that have controlled noisy activities through zoning restrictions include the St Lawrence Estuary MPA and The Gully MPA, both in Atlantic Canada.

Like MPAs, marine conservation areas established under the *Canada National Marine Conservation Areas Act*[xxiii] enable regulation of ocean noise by prohibiting activities that disrupt the health of marine ecosystems within their boundaries. A third form of federal marine protected area is a marine national wildlife area, which may also be used to protect against harmful underwater noise.[xxiv]

An Option for Comprehensive National Regulation

One option for regulation is to set criteria for noise exposure that should not be exceeded. The federal *Oceans Act* could be used for this purpose through its marine environmental quality guidelines provisions. DFO is "moving towards a more target-based program that focus on the development of standards and guidelines to improve or maintain Marine Environmental Quality"[xxv] A starting point would be adopting an overarching goal akin to the ocean noise indicator as used by the EU's Marine Framework Strategy Directive: that the introduction of energy, including ocean noise, into Canadian waters does not adversely affect the marine environment.

Accounting for the cumulative and combined effects of repeated exposure to sounds from different sources is important in considering new ways to regulate noise in Canada.

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[i] To date mitigation measures for underwater noise fall into two main categories: noise control at source and spatio-temporal restrictions of noise producing activities, such as setting exclusion or safety zones. Convention on Biological Diversity. Scientific Synthesis on the Impacts of Underwater Noise on Marine and Coastal Biodiversity and Habitats.CBD/CBD/SBSTTA/16/INF/12.Montreal, Canada. 93pp. 2012.

[ii] PROVISIONS FOR REDUCTION OF NOISE FROM COMMERICAL SHIPPING AND ITS ADVERSE IMPACTS ON MARINE LIFE, Report of the Correspondence Group, Submitted by the United States, DE 56/17, 12 December 2012, was submitted to the IMO's Design and Equipment Subcommittee in March 2012. There are other IMO procedures and tools that can be used to minimize shipping noise. For example, the IMO's Guidelines for the Designation of Special Areas and the Identification of Particularly Sensitive Sea Areas identify shipping noise as a pollutant that can adversely affect the marine environment and living resources of the sea. Canada has no PSSAs at present.

[iii] "Pollution" is broadly defined in the Directive to specifically include "human-induced marine underwater noise" (Article 3(8)). Moreover, the qualitative descriptors for demonstrating a "good environmental status" for the purposes of the Directive, listed in Annex I, specifically includes underwater noise, while the indicative list of pressures upon the marine environment, listed in Annex III, also includes this source of disturbance, citing "shipping, underwater acoustic equipment" as particular examples.

> Two suggested indicators for noise measures for Good Environmental Status have been proposed by a Task Group as follows:
>
> 11.1. Distribution in time and place of loud, low and mid frequency impulsive sounds
>
> — Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1ìPa 2 .s) or as peak sound pressure level (in dB re 1ìPa peak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)
>
> 11.2. Continuous low frequency sound
>
> — Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1ìÑa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1).
>
> Tasker, M. Amundin, M. Andre, A. D. Hawkins, W. Lang, T. Merck, A. Scholik- Schlomer, J. Teilman, F. Thomsen, S. Werner, and M. Zakharia, "Marine Strategy Framework Directive: Task Group 11 Report: Underwater noise and other forms of energy," European Commission and International Council for the Exploration of the Sea, Luxembourg, 2010. http://www.ices.dk/projects/MSFD/TG11final.pdf

[iv] Convention on Biological Diversity. Scientific Synthesis on the Impacts of Underwater Noise on Marine and Coastal Biodiversity and Habitats.CBD/CBD/SBSTTA/16/INF/12.Montreal, Canada. 93pp., 2012.at pg. 55

[v] Transport Canada, Frequently Asked Questions http://www.tc.gc.ca/eng/marinesafety/rsqa-csa2001-faq-2037.htm

[vi] *Canada Shipping Act*, 2001, SC 2001, c 26, s 6(c).

[vii] Pursuant to s.190 of the *Canada Shipping Act,* the Governor in Council may, on the recommendation of the Minister of Transport, make regulations respecting the protection of the marine environment. This includes the power to make regulations under s.190 (1) (h) "respecting the design, construction, manufacture and maintenance of vessels or classes of vessels."

[viii] Section 207(2)(b) of the *Canada Shipping Act*

[ix] Canada Marine Act , (S.C. 1998, c. 10) sections 56 and 58

[x] Department of Fisheries and Oceans. Statement of Canadian Practice: Mitigation of Seismic Sound in the Marine Environment, at: Date Modified: 2010-07-09.

[xi] Maritime Command Order: Marine Mammal Mitigation Procedures (MMMP), MARCORD 46-13, Volume 3A, date of review April 2008. Provided by Lieutenant Diane Larose from Navy Public Affairs.

[xii] Ford J.K.B., A.L. Rambeau, R.M. Abernethy, M.D. Boogaards, L.M. Nichol, and L.D. Spaven. 2009. An Assessment of the Potential for Recovery of Humpback Whales off the Pacific Coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/015.

[xiii] Canadian Environmental Assessment Act 2012, S.C.2012, c. 19, s. 52.

[xiv] See Ecojustice, Batholiths Backgrounder. A batholith is a large volume of previously molten rock, which has solidified and through erosion is now visible at the surface. In 2007, scientists had planned an expedition using a seismic ship in Douglas, Burke and Dean Channels to learn more about batholiths and the Coast Mountains. The proposal involved use of an array of 36 airguns that would be fired into the water every 20-60 seconds. A draft Environmental Assessment report (EA) found no significant environmental impact from the testing. Living Oceans Society contracted an independent review of the draft EA which found that in the immediate vicinity of the array, the sounds are reported to be 235 dB, can penetrate up to 50 km into the sea floor. The review predicted that whales and dolphins would be at risk of hearing damage if they were within 1,000-3,500 m of the array, as they would be exposed to 180 dB.

[xv] Canadian Science Advisory Secretariat, Science Response 2012/028 Science response to information requests submitted to the Enbridge northern gateway project environmental impact assessment hearings respecting ship strike risk and acoustic disturbance from shipping to whales.

[xvi] Convention on Biological Diversity. Scientific Synthesis on the Impacts of Underwater Noise on Marine and Coastal Biodiversity and Habitats**.**CBD/CBD/SBSTTA/16/INF/12.Montreal, Canada. 93pp. 2012. At pg 86, Weilgart at 1108

[xvii] *Species at Risk Act*, SC 2002, c 29.

[xviii] *David Suzuki Foundation v. Canada (Fisheries and Oceans)*, 2010 FC 1233 (CanLII).

[xix] *Fisheries Act*,RSC 1985, c F-14.

[xx] *Marine Mammal Regulations,* SOR/93-56, s. 7.

[xxi] DFO, NMFS, The Pacific Whale Watch Association. " Be Whale Wise - Marine Wildlife Guidelines for Boaters, Paddlers and Viewers. "

[xxii] *Oceans Act*, SC 1996, c 31, s.35.

[xxiii] *Canada National Marine Conservation Areas Act*, SC 2002, c 18.

[xxiv] Canada Wildlife Act (R.S.C., 1985, c. W-9)

[xxv] Danielson, H. and M. Stoneman, "Canada's Approach to Oceans Management & Current Status on Ocean Noise Initiatives", Presentation delivered at the WWF-Canada Ocean Noise in Canada's Pacific Workshop, 1 February 2012.