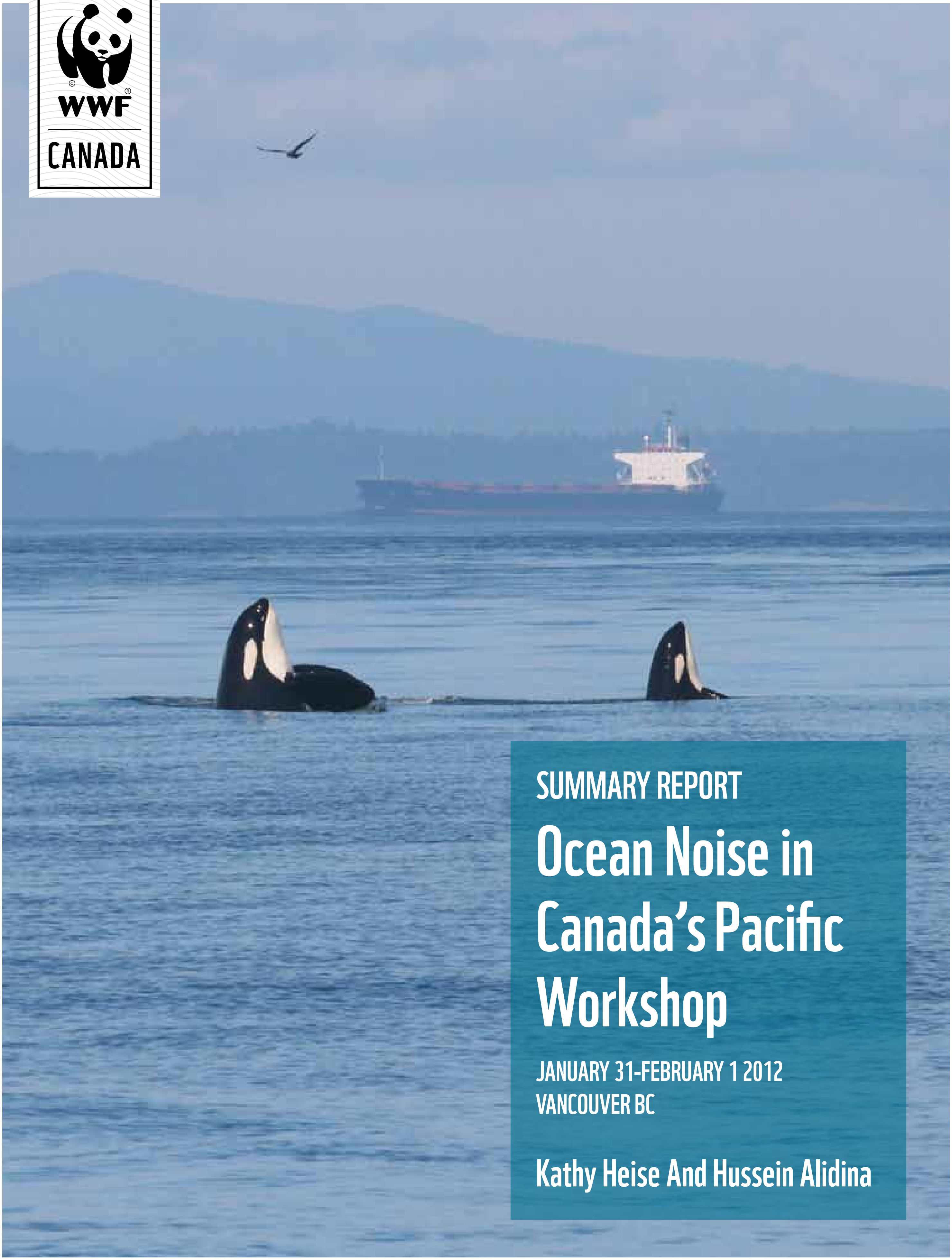

SUMMARY REPORT

Ocean Noise in Canada's Pacific Workshop

JANUARY 31-FEBRUARY 1 2012
VANCOUVER BC

Kathy Heise And Hussein Alidina

Front cover: Orcas and Tanker in Haro Strait.

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WWF is one of the world's most experienced independent conservation organizations, with over 5 million supporters and a global Network active in more than 100 countries. WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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EXECUTIVE SUMMARY

WWF-Canada's Ocean Noise in Canada's Pacific Workshop took place in Vancouver on January 31 and February 1, 2012.

A healthy acoustic environment is a necessary condition for healthy ecosystems and the species that utilize sound, but to date, there has been limited consideration of this issue in decision making and planning for existing and future uses of Canada's oceans. WWF-Canada convened this workshop to begin a dialogue toward better understanding and management of ocean noise on the Pacific Coast. The objectives of the workshop were to:

1. obtain a picture of ocean noise and its sources in the region, including monitoring, research, and science capacity.
2. identify the potential effects of anthropogenic ocean noise and related conservation concerns relevant to this region.
3. identify the kinds of knowledge and information needs that are most useful for advancing management of noise in the region.
4. discuss the short- to medium-term work needed to fill gaps in knowledge and generate products useful for noise management.

Almost 40 participants from a wide range of backgrounds (academia, non-governmental organizations, government agencies, port authorities, and consulting companies) attended the meeting. Although the majority of participants were Canadian, there was some representation from the United States, the U.K., and Australia. On the first day, speakers introduced the topic of anthropogenic noise and its potential impacts on marine life, described current research and monitoring activities in British Columbia, and catalogued current and emergent sources of underwater anthropogenic noise. On day two, a representative from the U.S. National Oceanic and Atmospheric Administration (NOAA) presented noise-mapping initiatives underway in the United States, and a bio-acoustician commissioned by WWF, Christine Erbe of Curtin University in Western Australia, presented work to quantify and map the annual noise contribution of shipping on the B.C. Coast (Figure 1).

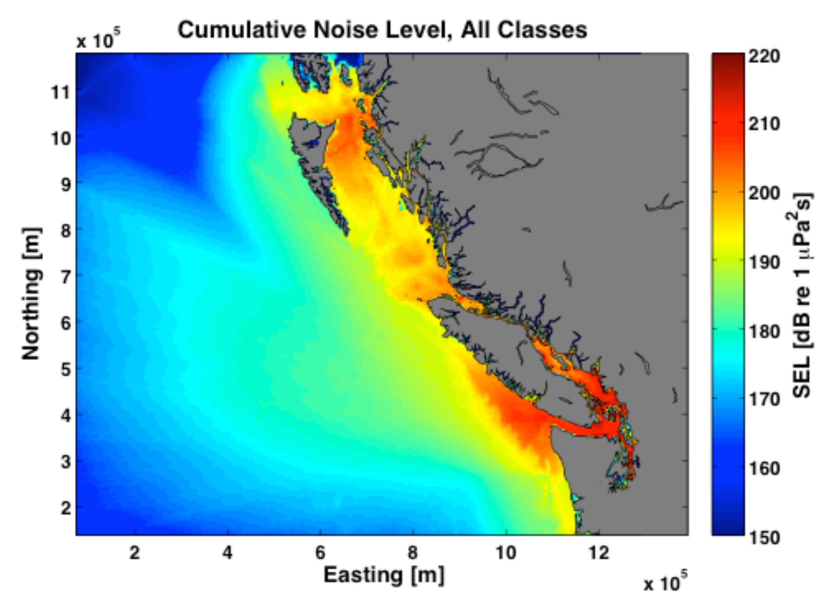

Figure 1: Cumulative annual shipping noise for 2008 on the B.C. Coast (Erbe, MacGillivray, & Williams, 2012).

Sessions on the second day focused on specific case studies of noise and noise management in other areas, and approaches to incorporate noise into future planning in British Columbia. The workshop ended with a roundtable discussion that identified the following short- and long-term actions.

SHORT-TERM ACTIONS (WITHIN SIX MONTHS)

1. Establish the currently known baseline levels of noise from existing data.
2. Generate potential scenarios of expected changes in noise levels from the full range of activities that are proposed and the potential biological effects on marine life.
3. Provide advice on equipment to those establishing new hydrophone networks.
4. Complete a map and database of existing hydrophone systems on the coast.

MEDIUM-TO LONGER-TERM ACTIONS

1. Integrate hydrophone networks through calibrating existing recorders and developing data protocols.
2. Inform placement for future hydrophones to address gaps in coverage of data and biological knowledge.
3. Provide management and policy recommendations for noise mitigation, including protecting acoustically quiet areas and setting marine environmental-quality targets for anthropogenic noise.
4. Provide input into regional marine protected area network planning.

A breakout discussion on hydrophone networks helped participants to share their expertise, knowledge of hydrophones, acoustic data collection, and standards. Participants later documented the location of their hydrophones and added them to an existing database and map of hydrophone networks on the Pacific Coast, facilitated by Scott Veirs of Beam Reach Marine Science and Sustainability School (Figure 2).

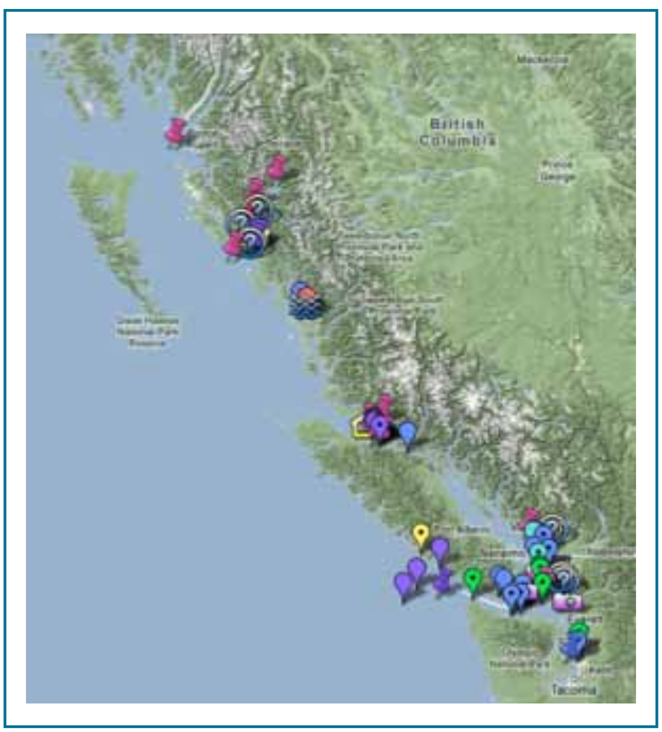

Figure 2: Hydrophone networks and locations on the B.C. Coast, courtesy of www.orcasound.net

A second breakout discussion on “hot spots” identified potential new locations where hydrophone networks could broaden our understanding of noise and animals on the B.C. Coast, particularly in biological hot spots. Suggestions included Brooks Peninsula, Dixon Entrance, Hecate Strait, and Money Point on the Central Coast.

The participants appreciated the timely nature of this meeting, given the scope of currently proposed developments on Canada’s Pacific coast and the likelihood of increased levels of anthropogenic noise and potential impacts on marine life. The workshop facilitated connections between people working on this issue, and identified a unique opportunity in the region to advance the consideration and treatment of anthropogenic ocean noise, given its existing hydrophone networks, community of researchers, and progressive ports.

This workshop statement was circulated at the end, which the majority of participants agreed with:

Ocean noise is a growing concern and its impacts must be considered in the management and planning of current and future activities in the marine waters off British Columbia. There is a need to protect quiet areas and reduce anthropogenic noise levels, especially in ecologically important areas.

REFERENCES

Erbe, C., MacGillivray, A., & Williams, R. (2012). Mapping ocean noise: Modeling cumulative acoustic energy from shipping in British Columbia to inform marine spatial planning. (Unpublished report submitted to WWF-Canada). Curtin University, Australia.

ACKNOWLEDGEMENTS

WWF-Canada would like to especially acknowledge Brandon Southall, John Hildebrand, Leila Hatch, and Michael Jasny, all of whom offered invaluable pre-workshop guidance as we developed the agenda. We would also like to thank Christine Erbe, Alex McGillvary, and Rob Williams for working tirelessly to complete the first-ever map of shipping noise for the B.C. Coast so that it could be presented at the workshop. Janie Wray, Paul Spong, and Helena Symonds contributed compelling images and audio recordings that reminded us as to why ocean noise matters. Most of all, WWF-Canada would like to thank all the participants of this first Ocean Noise in Canada's Pacific Workshop for their presentations and their perspectives, and for enriching the discussions during the two days. Their work on understanding and addressing anthropogenic ocean noise is an inspiration.

WWF-Canada would also like to especially thank Alan Dolan for helping plan the agenda and for facilitating this workshop. We are grateful to Romily Cavanaugh for her note taking and for preparing an initial summary of presentations which was used to inform the preparation of this report. We thank Ben Arsenault and Julie-Beth McCarthy, our volunteer note takers for their time. A very special thank you to Selina Agbayani for her outstanding efforts looking after all of the logistics that crop up during the course of organizing such a workshop. Kathleen McWilliam, Jacqueline Bjorkes, and the staff at the Listel Hotel made our time there so comfortable, and we are grateful for their hospitality.

The authors would like to acknowledge the support and guidance of Darcy Dobell, VP Pacific Region; and Linda Nowlan, director Pacific conservation WWF-Canada, for their support, continued guidance, and involvement in stewarding this workshop and project.

Last but not least, WWF-Canada is particularly grateful to the financial support of WWF-U.S. (Margaret A. Cargill Foundation), without which this workshop and undertaking would not be possible.

INTRODUCTION

It is increasingly being recognized that a healthy acoustic environment is a necessary condition for healthy ecosystems and the species that rely on sound. To date, however, there has been limited consideration of this issue in decision making and planning around existing and future uses of Canada's oceans. Recognizing this gap, WWF-Canada recently initiated a three-year project to improve consideration of anthropogenic ocean noise into ocean planning and management processes on Canada's Pacific coast. More specifically, this project involves working with the science and research community to facilitate the synthesis of information and products that can be useful to decision making and planning. WWF-Canada convened a two-day workshop to bring together the community of marine life and ocean noise researchers, regulators, citizen scientists, port authorities, and conservation interests in Pacific Canada. The workshop took place on January 31 and February 1, 2012, at the Listel Hotel in Vancouver.

The goal of the workshop was to begin a dialogue toward better understanding and managing ocean noise in Canada's Pacific. The objectives of the workshop were to:

1. obtain a picture of ocean noise and its sources in the region, including monitoring, research, and science capacity.
2. identify the potential effects of anthropogenic ocean noise and related conservation concerns relevant to this region.
3. identify the kinds of knowledge and information needs that are most useful for advancing management of noise in the region.
4. discuss the short- to medium-term work needed to fill gaps in knowledge and generate products useful for noise management.

Topics discussed at the workshop included an overview of ocean noise and its potential impacts on marine life; current acoustic research and monitoring in British Columbia; an overview of trends in shipping and other industries; noise-mapping initiatives; and case studies and approaches for anthropogenic noise management. Scott Veirs from the Salish Sea hydrophone network provided an existing map portal through which participants could add the locations of their hydrophones in order to provide a better sense of where acoustic data were being collected on the coast, and to help to identify gaps in coverage. Two breakout groups emerged at the workshop: one focused on integrating hydrophones networks and data standards, and the other focused on identifying future placement of hydrophones in relation to biological hot spots.

The majority of the workshop participants were from British Columbia, although there were a few individuals from outside the province, as well as from the United States, the U.K., and Australia. Participants included academic, government, and private researchers; and representatives from government agencies such as Fisheries and Oceans Canada (DFO), the Department of National Defence (DND),and Parks Canada; port authorities, consulting companies, and non-governmental and/or citizen science organizations such as OrcaLab, Cetacealab, Pacific Wild, TNC Canada, and the Vancouver Aquarium.

The following pages contain summaries of the presentations, but any errors in meaning or context are those of the report authors. The summaries have not been vetted by the original presenters at the meeting. The presentations appear here in the order that they were given at the workshop. Where the presentations had multiple authors, the name of the presenting author is noted with an asterisk (*).

AGENDA

TUESDAY (DAY 1) JANUARY 31, 2012

TIME	ACTIVITY	RESPONSIBILITY
8:00 – 9:00 a.m.	Continental breakfast; informal networking	All
9:00	Welcome	WWF-Canada
9:10	Introductions and expectations	Alan Dolan, Facilitator, All
9:20	Housekeeping, objectives, agenda review	Alan Dolan
GENERAL INTRODUCTION		
9:40	An overview of ocean ambient noise	John Hildebrand
10:25	Break	All
10:40	Marine mammals of B.C.: Distribution, relative abundance, important habitats, and future research directions	John Ford / Linda Nichol
11:10	Potential effects of noise on fish	Francis Juanes
11:40	Ecological constraints on sound production in marine animals: The importance of listening	Lance Barrett-Lennard
12:00 p.m.	**Lunch**	All
MONITORING AND RESEARCH IN AND NEAR B.C.		
1:00	Measurements of and trends in noise levels in the offshore waters of B.C. over the last 50 years	Ross Chapman
1:15	Assessing long-term sound profiles, including noise from anthropogenic sources in important resident killer whale habitat	Harald Yurk
1:30	The Salish Sea hydrophone network	Scott Veirs
1:45	Using pop-ups to measure underwater noise levels in 12 important whale habitats along the B.C. Coast	Rob Williams
2:00	A summary of over 40 years of acoustic monitoring in Johnstone Strait	Paul Spong / Helena Symonds
2:15	The Heiltsuk hydrophone network: Monitoring underwater acoustics on the Central Coast	Diana Chan / Jenny Brown
2:30	Orca, humpback, and fin whale acoustics of northern B.C.	Janie Wray
2:45	Monitoring ocean sound on cabled ocean observatories	Richard Dewey
3:00	**Break**	All
ACTIVITIES IN B.C.		
3:15	AUVs: An autonomous underwater vehicle overview	Doug Wilson
3:30	Shipping trends in the North Coast, into the port of Prince Rupert	Jason Scherr
3:45	Sustainable port growth and marine mammal protection initiatives in the Port of Vancouver	Darrell Desjardin
4:00	Other emerging/proposed activities in B.C.	Ben Wheeler
4:15	Further Q & A and discussion on talks presented today	Alan Dolan
4:50	Wrap-up and agenda review for next day	Alan Dolan
5:00	**Adjourn**	All

AGENDA
WEDNESDAY (DAY 2)
FEBRUARY 1, 2012

TIME	ACTIVITY	RESPONSIBILITY
9:00 a.m.	Welcome, agenda review	Alan Dolan
	NOISE MAPPING	
9:05	The U.S. NOAA Underwater Sound-Field Mapping Working Group: Developing geospatial tools to inform management of cumulative impacts on marine mammals	Leila Hatch
9:35	Modelling cumulative shipping noise in the B.C. Exclusive Economic Zone	Christine Erbe
10:25	**Break**	
	CASE STUDIES	
10:40	Integrating underwater noise within coastal and marine spatial planning frameworks: Lessons from Stellwagen Bank National Marine Sanctuary	Leila Hatch
10:55	How the Gully MPA is managed for underwater noise	Lindy Weilgart
11:10	Studies of vessel noise off southern California	John Hildebrand
11:25	An overview of the International Quiet Ocean Experiment (IQOE)	Christine Erbe
11:40	Rapid evolution: The management of ocean noise in other jurisdictions	Michael Jasny
12:05 p.m.	**Lunch**	All
	INCORPORATING NOISE INTO FUTURE PLANNING	
1:15	DND activities in B.C.	Kathy Heise
1:30	DFO science and policy on ocean noise	Mike Stoneman / Heather Danielson
1:50	Report on the Hydrophone Networks/ Calibration Working Group breakfast meeting	Ross Chapman
2:00	Report of the “Hot Spots” breakout lunch meeting	Richard Dewey
2:10	Roundtable discussion: Where do we go from here?	All
3:50	Did we meet our objectives?	Alan Dolan
4:00	Closing remarks	All
4:15	**Adjourn**	All

PRESENTATIONS DAY 1

I – GENERAL INTRODUCTION

An Overview of Ocean Ambient Noise

John Hildebrand, Scripps Institution of Oceanography, University of California, San Diego.

In the world's oceans, the three principal sources of anthropogenic noise are commercial shipping, military sonars, and seismic exploration. This presentation focused primarily on trends in shipping noise, and emphasized the importance of collecting baseline data. Shipping noise is a continuous source of broadband sound that is loudest at low frequencies, but can extend into the hundreds of kHz. At lower frequencies, propellers produce single-frequency tones, but at higher frequencies (above 100 Hz), cavitation noise dominates. Other sources of vessel noise include turbulence, gear noise, and auxiliary motors. While each ship may have its own acoustic signature, it is possible to characterize vessels by category, such as a container ship, or a vehicle or bulk carrier. The speed of a vessel also contributes to its noise profile, and even small boats such as whale-watching vessels can be a high-energy sound source into the 10–20 kHz range.

Shipping density maps can be produced through the Historical Temporal Shipping Model (HITS), which uses shipping statistics and route estimates to calculate the number of ships per degree latitude and longitude. In places such as the coast of Europe and the eastern United States, there can be as many as 10 ships per degree square. In the deep waters of the North Pacific, there is typically one ship per degree square.

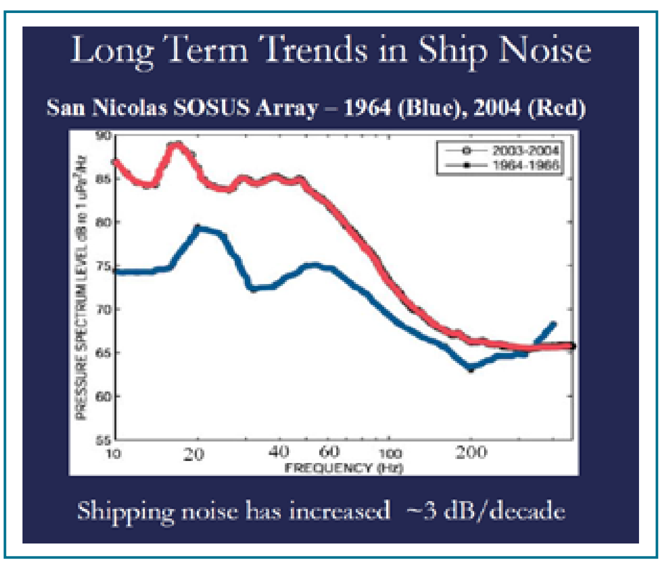

Figure 3: Noise levels from San Nicolas (off the coast of California) at two time periods three decades apart, courtesy of John Hilderbrand

The principal shipping port in the eastern Pacific is Long Beach, California. Hildebrand compared ocean noise at two sites off the coast: San Nicolas on the continental slope, and Eel Point on the continental shelf. Sounds from open ocean waters are detectable on the slope, whereas on the shelf, sound propagation is from local sources.

At the San Nicolas array, averaging yearly noise data from 1964 and comparing it with noise data from 2004 showed an increase in low-frequency noise (10–200Hz) of 3 dB per decade, which was attributable to shipping. There was a “bump” at the lower range of the spectrum (approximately 17 Hz) that shifted upward (to 20 Hz) in 2004, which Hildebrand attributed to increases in baleen whale numbers (Figure 3). A signal at approximately 300 Hz from fish that could be seen in the 1964 data was missing in 2004, likely due to overfishing. At the Eel Point array, increases in ocean noise averaged 1 dB per decade. Hildebrand noted that the economic downturn over the past four to five years has reduced the amount of shipping, although it appears to be increasing again now.

In July 2009, the California air-quality rule had unintended consequences on underwater noise levels. The law required all vessels to burn cleaner fuel within 24 miles of the coast, which resulted in ships altering their route seaward. This in turn resulted in quieter noise levels in the nearshore Santa Barbara Channel. For every fewer ship in the channel, the average ambient noise declined approximately 1 dB.

In May 2010, the Deepwater Horizon oil spill in the Atlantic resulted in a significant increase in shipping noise associated with the capping of the well and the cleanup. Although there was not pre-existing baseline noise data, measurements at 400 Hz were used as a proxy for shipping noise. During a hurricane in late July, the majority of ships went into port, background noise level declined by 15 dB, corresponding with a significant increase in beaked whale calls.

Two other significant sources of anthropogenic ocean noise are airguns for seismic surveys and military sonars. Airguns dominate the soundscape in the Atlantic Ocean, and there is an alarming increasing trend in their use in the Arctic. There are relatively few seismic surveys on the west coast of North America. However, military sonars are used in the west coast training ranges. On an annual basis, Hildebrand reported 55,740 mid-frequency sonar pings detected at the SOCAL site off southern California.

The presentation concluded with some recommendations for future research:

- Characterize noise sources.
- Determine the locations of the noise sources.
- Develop propagation models from the source area.
- Assess long-term trends in noise.
- Encourage the development of new quieting technologies.

Marine Mammals of British Columbia: Current Status, Distribution, and Critical Habitats

John Ford and Linda Nichol, Cetacean Research Program, Pacific Biological Station, Nanaimo, B.C.*

The B.C. Coast has a high diversity of habitats and of marine mammals, with 25 species of cetaceans, 5 pinnipeds, and 1 mustelid (the sea otter). Historically, marine mammals were vulnerable to harvesting, with more than 25,000 whales taken off the coast between 1908 and 1967. Sea otters were also harvested to extinction in British Columbia, but their numbers are now recovering, after a series of introductions in the 1960s. This presentation focused primarily on cetaceans.

Since 2002, the Cetacean Research Program (CRP) has undertaken annual ship surveys, using standardized survey protocols, and deploying smaller vessels for photo identification and biopsy sampling. During approximately 40,000 km of surveys, they have had over 30,000 cetacean sightings, which have been used for population abundance estimates using DISTANCE software. The results show a strong recovery of humpback whales and identify some coastal hot spots where animals concentrate. Blue whale sightings are rare, but fin whales are occasionally seen in inshore waters, including a significant number in Whale Channel and Caamaño Sound on the Central Coast. The CRP also undertakes passive acoustic monitoring (PAM) using submersible recorders (PATC and AURAL) for deployments ranging from six months to one year (Figure 4). It also has nine deployment sites for land-based hydrophones, including Langara Island, Caamaño Sound, and lower Johnstone Strait. The B.C. Cetacean Sightings Network is another source of information on cetaceans. Although records provide "presence only" information, in some cases useful patterns emerge from the data. One example is the 5,000-plus sightings of Pacific white-sided dolphins, which have revealed a relatively recent shift into Howe Sound.

Critical habitats for humpback whales have been identified off southwest Vancouver Island, Langara Island, southeast Moresby Island in Haida Gwaii, and around Gil Island on the Central Coast. Small-boat surveys revealed that humpback whales were more abundant around Gil Island in the fall. Photo identification has shown the highest number of matches between Langara and southwest Moresby islands, and the lowest between southwest Vancouver Island and the other three areas.

Historically, grey whales were thought to migrate along the outer B.C. Coast, but whales tagged off the west coast of Vancouver Island have shown that the migration route is through Hecate Strait and Dixon Entrance. This route overlaps with shipping corridors and puts grey whales at higher risk for anthropogenic impacts. The NaiKun Wind Energy proposal for Haida Gwaii will potentially ensonify the entire migration corridor for grey whales during the construction phase.

There are three populations of killer whales on the B.C. Coast, each of which needs to be treated as a different species because they are so different in their foraging and acoustic behaviours. The fish-eating northern and southern resident killer whales have different distributions and critical habitats. For the northern residents, potential critical habitat has been identified in Caamaño and Fitz Hugh sounds, and Johnstone Strait has been designated critical habitat. Juan de Fuca Strait and the southern Salish Sea have been designated as critical habitat for the southern residents. Acoustic monitoring has revealed that the Swiftsure Bank off southern Vancouver Island is used by both northern and southern residents and may also be critical habitat.

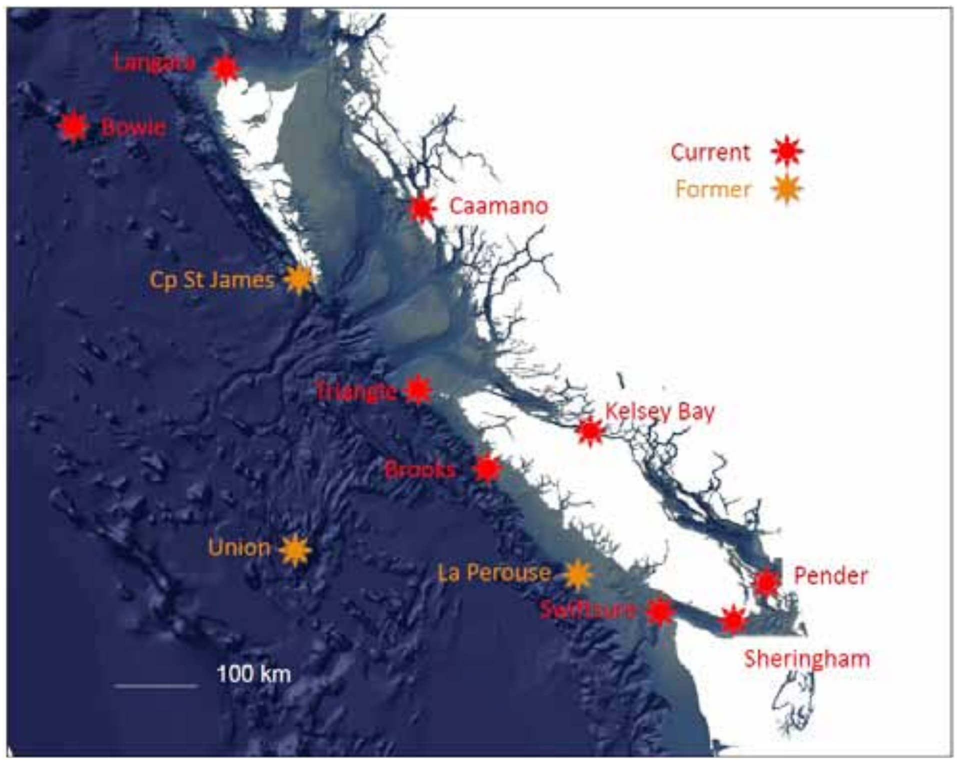

Figure 4: Cetacean Research Program (DFO) acoustic recorder locations, courtesy of John Ford

Potential Effects of Noise on Fish

Francis Juanes, [1] and Rodney Rountree,[2] [1]Dept. of Biology, University of Victoria; [2]University of Massachusetts, Amherst, Mass.*

Worldwide, more than 700 species of fish have been found to actively produce sounds, although only a relatively small proportion of over 30,000 species of fish have been tested. Their sounds range from simple to complex, and can be produced through stridulation (rubbing or scraping of fins, bones, or teeth), passing air through their mouth, gills, or anus, and/or by drumming (using muscles that push/pull on the air/swim bladder). They produce sounds during spawning and/or courtship behaviour, under distress, as an aggressive or territorial display, and possibly as a component of predator–prey interactions. Males make the majority of sounds. In cod, the drumming muscles are larger in males than in females, and they increase in size during spawning. In haddock, the sounds produced vary with the stage of courtship the fish are engaged in.

Soniferous fish can be monitored passively using Autonomous Underwater Listening Stations (AULS), Remotely Operated Vehicles (ROVs), and ISIS video systems. Fish sounds can be used to identify essential fish habitat (EFH), to locate spawning habitats and locations, and to census marine life. Although different species spawn at different times of the year, at any point in time, fish are spawning in the ocean environment. Specific examples of how sound is used by listeners include the sunset call choruses of striped cusk-eels, which are used to detect their range extension into an area where they were formally unknown. They are also used to identify spawning sites for commercially important species such as haddock, cod, and other groundfish using AULS. Passive acoustics were also used to monitor the invasion of the freshwater drum into the Hudson River.

Fish have two inner ears, with a structure similar to other vertebrates. Sensory hair cells convert sound to electrical signals. These hair cells can be fatigued, damaged, or destroyed by high-intensity sounds. However, unlike mammals, fish can replace or repair damaged sensory cells given time and protection from predation. Specific examples of responses of fish to sound include pile driving, which resulted in direct mortality in surfperches. Rockfish have shown startle and alarm responses to airguns, with fish forming tighter schools that moved to the sea floor and became stationary. Lower-intensity but longer-term sounds, such as shipping noise, may have more behavioural and physiological effects on fish, although these are not yet well understood. Herring have shown diving reactions in response to fishing trawls. Catches of cod in the vicinity of a seismic survey declined significantly during the survey. Salmon and cod likely detect wind farm sounds up to 25 km, but there is little evidence that those sounds can cause temporary or permanent hearing damage. However, they may cause

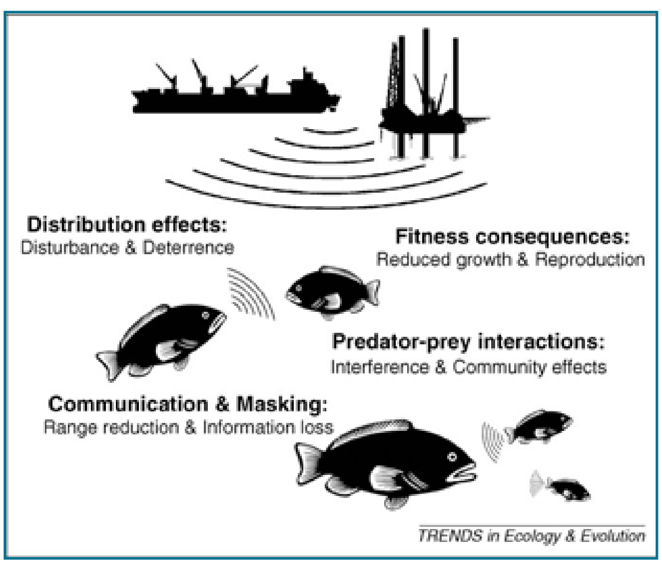

Figure 5: Research areas for investigating potential effects of noise on fish from Slabbekoorn et al. 2010

acoustic masking, avoidance responses, or physiological stress, and the sounds associated with construction may have higher impacts on fish than so those during the operational phase. The population-level consequences of chronic noise are not well understood. It is unknown how fish distribution changes in response to noise or what effects it may have on reproductive success. It may mask communication signals and/or cause masking effects in predator–prey relationships (Figure 5).

Presentation References:
Slabbekoorn, H., Bouton, N.,van Opzeeland, I., Coers, A., ten Cate, C. & Popper, A.N. (2010). A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution: 25: 419-427.

Ecological Constraints on Sound Production in Marine Animals: The Importance of Listening

Lance Barrett-Lennard, Cetacean Research Program, Vancouver Aquarium, Vancouver, B.C.

Sounds can be used both actively and passively by marine animals. They use it actively for:

- social communication (for making contact and conveying status, to maintain group cohesion, to mediate interactions, and for territorial defence);
- intergroup and interspecies communication (to intimidate rivals or predators, to avoid competition, and for territorial defence);
- hunting and foraging (prey detection and localization, often using short- to medium-range echolocation, and prey manipulation); and
- object detection (using long-range echolocation).

Animals use sound passively (by listening) to:

- detect predators and rivals (by hearing vocalization, incidental sounds, and alarm calls);
- hunt and forage (hearing prey's vocalizations and other incidental sounds, disruption of sound fields, and the echoes of sound from other sources); and
- orient and navigate (by referring to consistent sounds such as waterfalls and surf noise, assessing reverberation and resonance of external sounds, and using acoustic signposts).

Using sound actively has costs, including attracting predators and rivals, and alerting prey, as well as the increased energy associated with producing it. Marine mammal-eating transients favour passive listening over echolocation, so as to not alert their prey. Fish-eating residents use echolocation 27 times more frequently than do transients, and echolocation use per individual decreases as group size increases, suggesting that animals share information from their echolocation signals. Dolphins and porpoises likely travel using passive listening much of the time, given attaching acoustic reflectors to nets as a means to reduce entanglements in fishing nets has not worked. Active "pingers" attached to nets have been more successful in reducing entanglement.

Increased noise levels can impair passive listening by making it more difficult for predators to locate prey, to navigate and orient silently, to impair communication, and to avoid competition. Noise can mask swimming sounds, which may make it more difficult for prey to detect predators, although it may acoustically screen prey from predators. On balance, noise is likely to be more harmful to predators that use passive listening (such as transient meat-eating killer whales) than to prey; some species may be affected by chronic noise much more than others.

II – MONITORING AND RESEARCH IN AND NEAR BRITISH COLUMBIA

Low-Frequency Ambient Noise Measurements and Trends in Offshore B.C. Waters

Ross Chapman, School of Earth and Ocean Sciences, University of Victoria, Victoria, B.C.

Between 1978 and 1986, ambient noise measurements were made in deep water off the west coast of Haida Gwaii and the Columbia River. These Deep Research Eastern Pacific (DREP) measurements used a multi-element volume array (MEVA) with eight vertical and four horizontal calibrated hydrophones deployed at 400-m depth in the deep sound channel. Recordings were made during "quiet" periods of no shipping in the area, and broadcast by radio frequency to calibrated receivers on the research vessel. All noise-generating equipment on board was shut off during the recording period.

Chapman found that deep ocean noise was dominated by distant shipping, and that it was possible to determine the direction that noise was coming from. At 31 and 250 Hz, most of the noise was propagated horizontally from the east by downslope enhancement from distant sources on the continental shelf. It was not coming from sources within the sound channel. Wind and wave noise from higher latitudes also contributed to the soundscape, although to a lesser degree. Up to 1980, the trend in increasing noise was approximately 0.5 dB per year, or 5 dB per decade. After 1980, the rate of increase in the deep ocean was approximately 0.15 db per year. However, in shallow water, the trend was significantly greater and more variable over time (Figure 6). These measurements were consistent with the trend in increasing noise observed in measurements made by Wenz in the 1960s and those made by Hildebrand and colleagues in the 2000s.

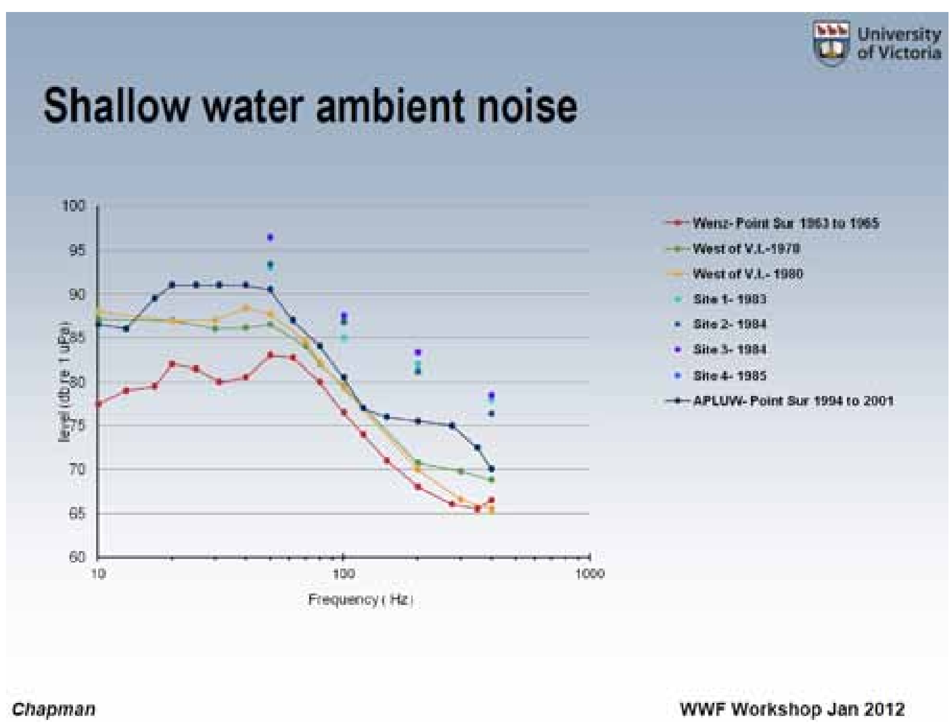

Figure 6: Shallow water ambient noise 1963 to 2001 off the BC coast, courtesy of Ross Chapman

Assessing Long-Term Sound Profiles, Including Noise from Anthropogenic Sources, in Important Resident Killer Whale Habitat

Harald Yurk,, [1], [2] Paul Cottrell,[3] and John Ford.[3] [1]Simon Fraser University, Burnaby, B.C., [2]Vancouver Aquarium, Vancouver, B.C., and [3]Department of Fisheries and Oceans Canada, Nanaimo.*

Sounds that are important to killer whales are determined by the whales' hearing range and perception. Certain frequencies and intensities are useful for orientation, foraging, and social communication, and some acoustic signals are directional. This project has four main goals:

- To determine changes in sound levels over time with reference to different sound sources and their relative contribution to overall received levels
- To determine sound propagation loss within the habitat relative to the type of sound source
- To characterize a habitat acoustically; for example, determine influences of underwater topography, currents, wind, and anthropogenic inputs on sound levels and propagation characteristics
- To determine absolute and relative sound-exposure levels for animals spending time in the habitat.

In order to do this, the project is using stationary hydrophone arrays at various locations within the Salish Sea to record sounds continuously over multiple years. The locations differ in their vessel traffic patterns and in their ecological importance to killer whales. Vessel noise is quantified at a range of frequencies up to 16 kHz. Mobile recordings are also being made to record sounds at different depths, in different habitats, and in the presence and absence of vessels and whales. Test signals are also being used to quantify received levels at the stationary arrays. Although it is early in the analysis phase, Yurk noted that there was often significant noise above 100 dB, which would mean whales would have to increase their call volume in order to be heard by conspecifics.

The Salish Sea Hydrophone Network

Scott Veirs,, [1] Val Veirs,[1] and Jason Wood,[2] [1]Beam Reach Marine Science and Sustainability School, Seattle, Wash., and [2]The Whale Museum, Friday Harbour, Wash.*

The Salish Sea hydrophone network has five cabled hydrophones (www.orcasound.net) in the designated critical habitat of southern resident killer whales that publicly transmit underwater sounds in real time. A human listening network has been established, with approximately 10 dedicated listeners and 160 on social media. Twelve per cent of listeners are outside the United States, including 6 per cent in the U.K. and 4 per cent in Canada. The website receives approximately 5,000 hits per month, and the system can support up to 30 listeners at a time (although this was exceeded four times in 2011). There is also live audio streaming into four public spaces, including the Seattle Aquarium, in an effort to increase public awareness of the importance of underwater sound.

Listeners are encouraged to log their observations of killer whale calls and other sounds in a publicly available database. The project supplements the killer whale sighting network to determine when killer whales are in the area. Underwater noise levels from 100 Hz to 100 kHz are monitored; automatic detection and recording software (WhoListener, developed by Val Veirs) computes calibrated two-second mean received sound levels, and 20-minute broadband means and spectrum levels. The software will also trigger recording on unusual sounds (such as military sonars) and uploads these recordings to a database for human classification. Ship noise dominates the noise budget of the area, and a passing ship typically travelling at 15 knots increases the ambient noise by approximately 20 dB for 20 minutes as it passes through. For 577 recorded ships in Haro Strait, the source level increased with the speed of the vessel by approximately 0.3–1 dB per knot. In summer, whale watching and recreational vessel noise increases ambient noise levels 3 dB over winter levels (Figure 7). All data is archived and processed to monitor underwater noise levels over the long term.

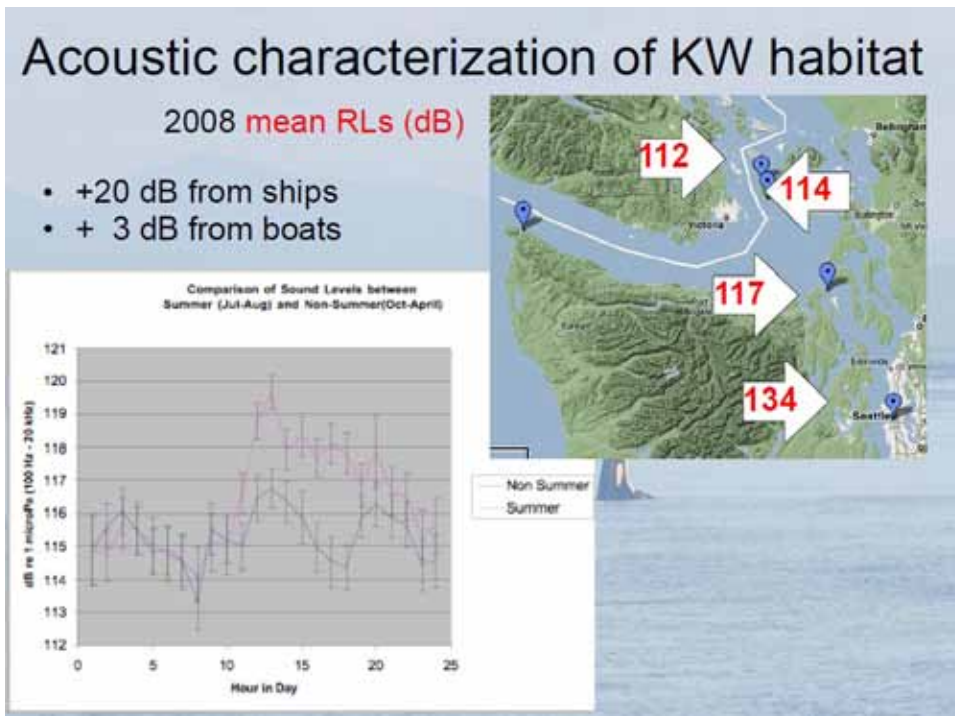

Figure 7: Salish sea hydrophone network - summer and winter ambient noise levels, courtesy of Scott Veirs

Using Pop-Ups to Measure Underwater Noise Levels in 12 Important Whale Habitats Along the B.C. Coast

*Rob Williams, *, [1], [2] Erin Ashe,[2] Christopher Clark,[3] and Dimitri Ponirakis.[3] [1] University of St. Andrews, Scotland, [2]Oceans Initiative, B.C. and [3]Cornell University, N.Y.*

Williams described a three-year study (2008–2010), Chronic Ocean Noise: Cetacean Ecology and Acoustic Habitat Loss (CONCEAL), to characterize underwater noise at 12 sites and to determine what implications this might have for masking communication signals for fin, humpback, and killer whales (Figure 8). Recordings were made at Triple Island, Caamaño Sound, Kitimat Arm, Kitkiata Inlet, Broughton Archipelago, Blackfish Sound, Robson Bight, Georgia Strait, and Haro Strait. There was a great deal of variability among the sites, and within days at certain sites, although some were chronically noisy. Williams showed an animation of the acoustic footprint (at 1 kHz) of a container ship transiting through the Juan de Fuca Strait and Salish Sea, demonstrating how the sound would propagate through different portions of the habitat. He described scenarios for communication signals for fin (17–28 Hz), humpback (71–708 Hz), and killer whales (1.5–3.5 kHz) in areas of low, moderate, and busy shipping traffic, as well as how the acoustic space for each species to communicate was reduced with increasing vessel traffic. Humpback and killer whales were particularly vulnerable, with over 80 per cent of their acoustic habitat lost in high shipping areas.

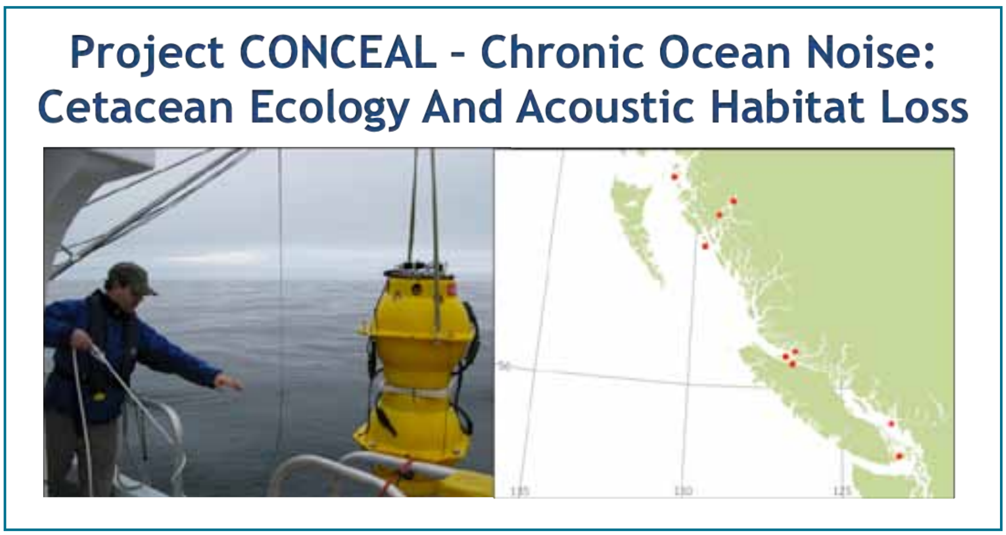

Figure 8: Project CONCEAL pop-ups and acoustic recording locations, courtesy of Rob Williams

Prior to using pop-ups, Williams undertook a controlled study in which killer whales were exposed to differing levels of boat traffic and their behavioural responses were systematically recorded (Williams, Lusseau, & Hammond, 2006). He also undertook surveys for whales in 2004 and 2005 on the B.C. Coast (Williams & Thomas, 2007) and overlaid it with vessel traffic to created density surface maps to estimate the likelihood of ship strikes for fin, humpback, and killer whales (Williams & O'Hara, 2010).

Presentation References:

Williams, R., Lusseau, D., & Hammond, P.S. (2006). Estimating relative energetic costs of human disturbance to killer whales (Orcinus orca). Biological Conservation, 133, 301–311.

Williams, R., & Thomas, L. (2007). Distribution and abundance of marine mammals in the coastal waters of B.C., Canada. Journal of Cetacean Research and Management, 9(1), 15–28.

Williams, R., & O'Hara, P. (2010). Modelling ship strike risk to fin, humpback and killer whales in British Columbia, Canada. Journal of Cetacean Research and Management, 11, 1–8.

OrcaLab: A Summary of over 40 Years of Acoustic Monitoring in Johnstone Strait

Paul Spong and Helena Symonds, OrcaLab, Hanson Island, B.C.

OrcaLab is a year-round field research station on Hanson Island in Johnstone Strait on northern Vancouver Island with a network of six remote hydrophones to monitor underwater acoustics in approximately 50 sq. km of northern resident killer whale critical habitat. The positioning of the hydrophones allows listeners to track vocally active whales acoustically as they move in and out of the area. Over time, the authors have learned to recognize individual family groups owing to distinctive features of their dialects. Recordings are made whenever killer whales are detected, and the best ones are often at night, when there is less boat noise. Commercial whaling in Canada stopped in 1967, and since 1982, humpback whales have slowly been returning to the area. Now they are seen almost daily from May through November, and are being recorded.

OrcaLab has live-streamed audio for the past 12 years at www.orca-live.net using a wireless network of five microwave radios on four islands. George Tzanetakis and Steven Ness at the University of Victoria have worked on building an archive of 20,000 hours of OrcaLab recordings, some of which are publicly available at www.orchive.cs.uvic.ca.

Vessel noise is problematic in this area, particularly, but not limited to, that associated with tugs towing log bundles that move slowly through the area, typically taking eight hours to transit 5 km. Killer whale calling is reduced during this time (Figure 9). There are multiple other sources of underwater noise, including recreational and sportfishing boats, fishing boats, ferries, cruise ships, and freighters. The authors want to see improved efforts to reduce underwater noise.

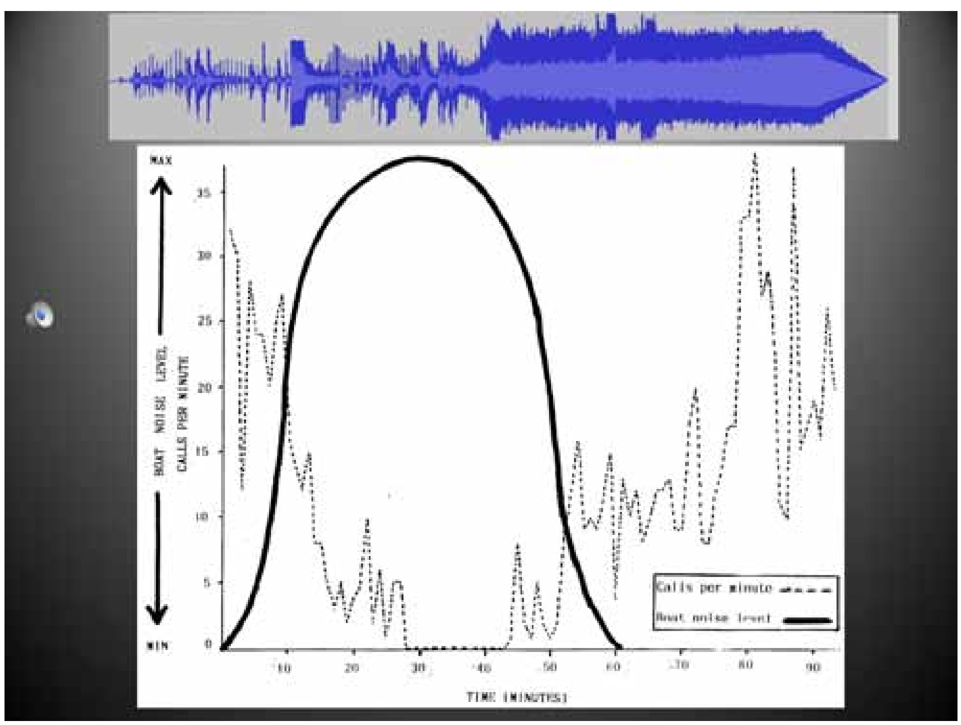

Figure 9: Reduction of Killer Whale calls in presence of boat noise in Johnstone Strait, courtesy of OrcaLab

Heiltsuk Hydrophone Network: Monitoring Underwater Acoustics on the Central Coast

Diana Chan, Conservation Biologist, Pacific Wild, Bella Bella, B.C.

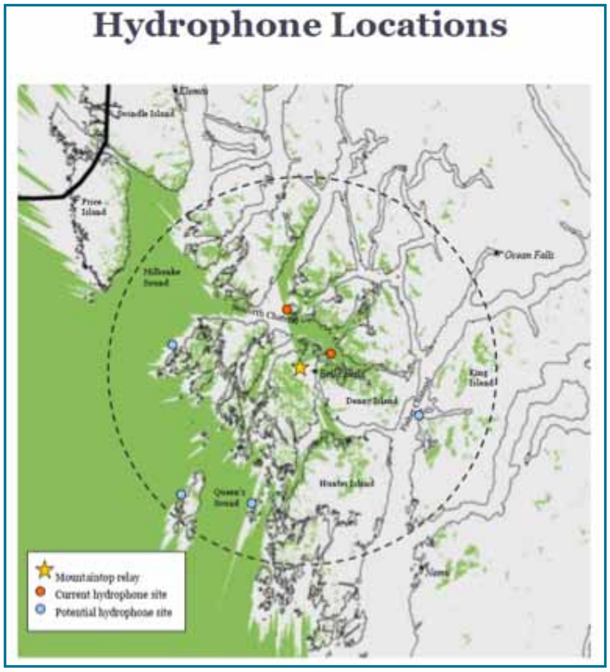

Figure 10: Heiltsuk Hydrophone Network
- current and proposed hydrophone sites, courtesy of Pacific Wild

This project is an initiative of the Heiltsuk First Nation, and is in the early stages of development. Ultimately, the goal is to establish a network of hydrophones that can be used in future marine planning efforts and in community outreach, and that will provide hydrophone coverage between OrcaLab in the south and Cetacealab to the north. Hydrophone signals are transmitted over FM radio via mountaintop relay sites to the nearby community of Bella Bella, including into the local school, and are powered using both solar and wind energy. At present, there are two hydrophones in place in Seaforth Channel, and three others are proposed (Figure 10).

Orca, Humpback, and Fin Whale Acoustics of Northern British Columbia

Janie Wray, Cetacealab, Gil Island, B.C.

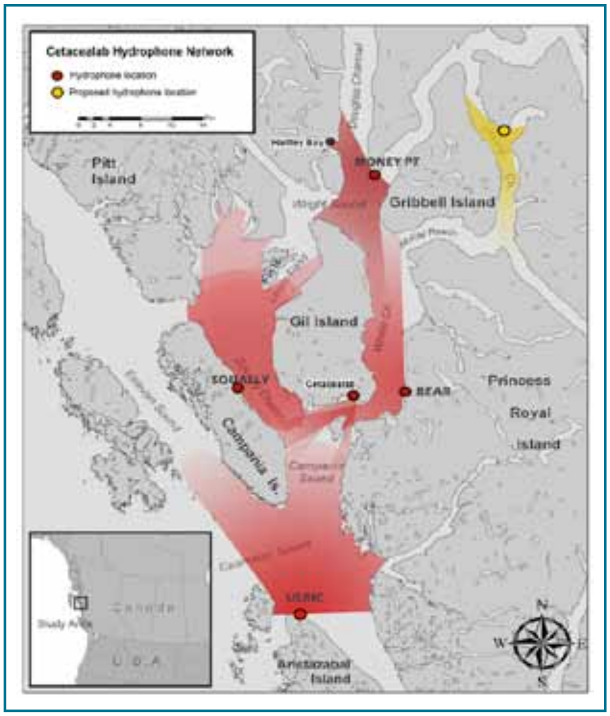

Figure 11: Cetacea Lab Hydrophone station locations, courtesy of Janie Wray

Cetacealab has been operating a network of remote hydrophones to document the occurrence and acoustic activity of whales on the northern B.C. Coast since 2003. At present, they have four uncalibrated hydrophones in place that capture the soundscape around Gil Island on the central north coast (Figure 11). Sounds are broadcast into the First Nations village of Hartley Bay, which has given the residents an understanding of how boat noise could have an impact on marine mammals, and has resulted in changes to their boating behaviour. Cetacealab has documented northern resident killer whales in the area in all months of the year, with detection rates highest in June and July. Beginning in 2009, visual identification of individual whales from a shore-based station in Caamaño Sound was undertaken, which supported the acoustic detection results. Cetacealab has also documented an increase in usage of the area by humpback whales for both foraging and socializing. Males sing and compete with each other for females, and use sound to coordinate bubble net feeding. Fin whales were first observed in 2006, and since 2009, they have been sighted regularly. Humans cannot readily hear the sounds made by fin whales, but acoustic recordings are made when the whales are detected visually.

Monitoring Ocean Sound on Cabled Ocean Observatories

Richard Dewey, Associate Director, VENUS, University of Victoria, Victoria, B.C.

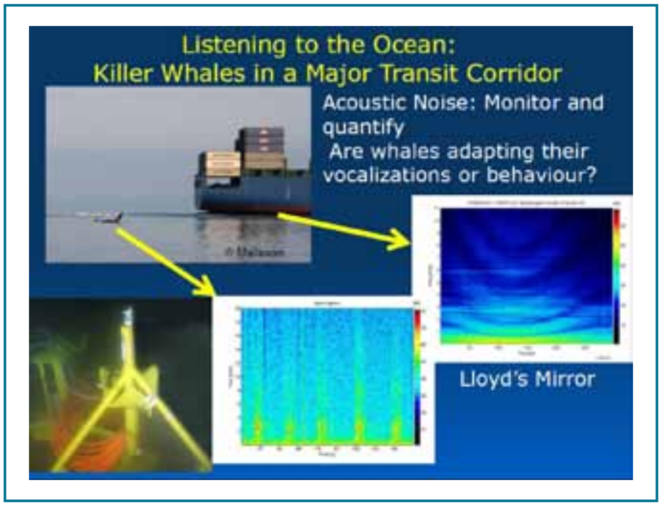

Figure 12: Acoustic recordings from VENUS, courtesy of Richard Dewey

In British Columbia, there are two ocean observing systems (OOS) that host a number of instruments, including hydrophones that monitor the underwater acoustic environment: VENUS (www.venus.uvic.ca) and NEPTUNE (www.neptunecanada.ca). The NEPTUNE network extends 250 km off the west coast of Vancouver Island out to Endeavour Ridge, with hydrophones at two of the six nodes. The VENUS network extends into the Salish Sea, with hydrophones placed on two of the three nodes. The VENUS hydrophones provide a constant record of all vessels in and out of Vancouver harbour. The nodes also record CTD (Conductivity, Temperature and Depth), and have a 200-kHz echo sounder and sediment trap, ADCP (Acoustic Doppler Current Profiler), among other equipment. The hydrophones are calibrated and record broadband ambient sounds ranging from marine mammals to wind and wave action, and are broadcast live with a 10-minute delay (Figure 12). Low-frequency hydrophones (icListen) that detect sounds from 1 to 1,600 Hz are currently being tested on the sites. The NEPTUNE hydrophones are also linked to the global website Listening to the Deep Ocean Environment (www.listentothedeep.net).

"AUVs," an Autonomous Underwater Vehicle Overview

Doug Wilson, Imagenex Techonology Corp., Port Coquitlam, B.C.

Autonomous underwater vehicles (AUVs) are free-swimming vehicles that are used for a wide variety of purposes and can be equipped with a range of technologies. Imagenex provides a range of sonar equipment for them. AUVs can be used anywhere, including the Mariana Trench and under ice in the Arctic and Antarctic. Some have acoustic modems to communicate, whereas others, such as ocean gliders, pop up to the surface for wireless communication and GPS fixes. They can range in size from the 16-cm-long Robo-Jelly to the 4-m-long Atlas-Marum's family of large, defence industry-oriented AUV with multiple capabilities and options. They have been used for a range of tasks, from finding airplane wreckage to transAtlantic crossings. AUVs are used to carry equipment for oceanographic and biological measurements, and for surveillance and monitoring, including a range of sonars. Hydrophones are not standard equipment on most AUVs, due to the problem of self-noise, since they have active acoustics such as doppler velocimeters, obstacle avoidance sonars, and acoustic modems. Hydrophones are standard equipment on Wave Gliders, which were in part developed for marine mammal research, and are less noisy and better suited to low-energy, long-term monitoring applications such as noise assessment.

III – ACTIVITIES IN BRITISH COLUMBIA

Shipping Trends and Future Activity on British Columbia's North Coast

Jason Scherr, Prince Rupert Port Authority, Prince Rupert, B.C.

The port of Prince Rupert (www.rupertport.com) is large (14,000 ha), with more than 350 km of coastline, and the port authority's goal is to become a leading trade corridor between North American and Asian markets. Ridley Terminal (www.rti.ca) loads metallurgical and thermal coal, petroleum coke, and wood pellets, and has significant capacity for growth and diversification. It loads at a rate of 9,000 tonnes per hour, has an annual shipping capacity of 16 million metric tonnes, and storage capacity of 1.2 million metric tonnes. It can handle 250,000 DWT vessels, but is capable of handling VLCC vessels of 350,000 DWT. Prince Rupert Grain Ltd. has the capacity to ship 7 million tonnes a year, can load up to 4,000 tonnes of wheat or barley an hour, and can berth ships to 145,000 DWT. The Fairview Container Terminal loads and unloads railway cars, and in 2010 loaded 3.5 million metric tonnes. In 2010, total port-wide traffic was 16.5 million metric tonnes.

Vessel traffic ranged from 30 to 52 vessels per day within the Dixon Entrance area during a six-day period in July–August 2011. Vessel types include merchant ships (container, tanker, cruise ship, and general cargo), as well as tugs and barges, fishing vessels, government vessels, and pleasure craft. It is the busiest port on the north coast: 358 vessels entered the port in 2010, compared with 47 for the port of Kitimat. The majority were bulk carriers (50.8%) and container ships (24.4%), but also included tankers (6.5%), cruise ships (6%), tugs and barges (6%), and general cargo (6%) (Figure 13).

There are plans for growth of the port to encompass all of Ridley Island by 2020, with a significant expansion of the terminals and bulk facilities to facilitate increased shipping. The challenge will be to balance unprecedented demand with conscious growth, and as such, the port has joined the Green Marine Program. It is undertaking baseline studies of water and air quality, an inventory of its contaminated sites, and a noise (in air) study.

PRINCE RUPERT PORT AUTHORITY

YEARLY VESSEL TRAFFIC FOR NORTH COAST PORTS

YEAR	PRINCE RUPERT	KITIMAT	STEWART	TOTAL
2009	311	72	8	391
2010	380	47	8	435
2011	406	67	12	485

2010 VESSEL TYPE BREAKDOWN

Bulk Carriers - 50.8%	Cruise Ships - 6%
Container Ships - 24.4%	Tugs/Barges - 6%
Tankers - 6.5%	General Cargo - 6%

Figure 13: Slide showing vessel traffic for North Coast Ports, courtesy of Jason Scherr, PRPA

Port Metro Vancouver-Marine Mammal Monitoring Program and Initiatives

Darrell Desjardin, Director, Sustainable Development, Port Metro Vancouver, Vancouver, B.C.

Vancouver is the largest and busiest port in Canada, and the largest in North America in terms of total foreign exports. It includes 623 km of shoreline and extends 24 nautical miles into the Salish Sea. It handled more than 188 million tonnes of cargo in 2010, and it is predicted that shipping will continue to grow well into the future. Shipping is a very efficient way of transporting cargo and adds a relatively small percentage (1–2%) to the production cost of consumable items. In 2010, there were 2,600 ship arrivals, including 177 cruise ships, and the average vessel size was 43,460 gross tonnes; over 190 tugs were active in the port.

Ships are getting larger because they are more efficient to operate. A typical container ship travelling from Prince Rupert to Vancouver to Long Beach, California, would consume 200 tons of fuel per day travelling at 20 knots, and would complete the trip in 4.2 days. A handymax bulk carrier could carry 40,000 tons and would consume 30 tons of fuel per day. The Emma Maersk is the largest container vessel in Europe (397 m) and would take 9 days to unload here.

With the growth in shipping, there is a need to expand the Deltaport, and there is concern for southern resident killer whales because this construction is taking place in their critical habitat. Construction concerns are the potential noise associated with pile driving, vibro densification, and dredging, as well as operational concerns associated with vessel traffic. Mitigation methods include the use of bubble curtains (to attenuate the sound) and the use of visual monitors for killer whales within a 1-km radius. There are also other marine mammal species that use this area that may be affected.

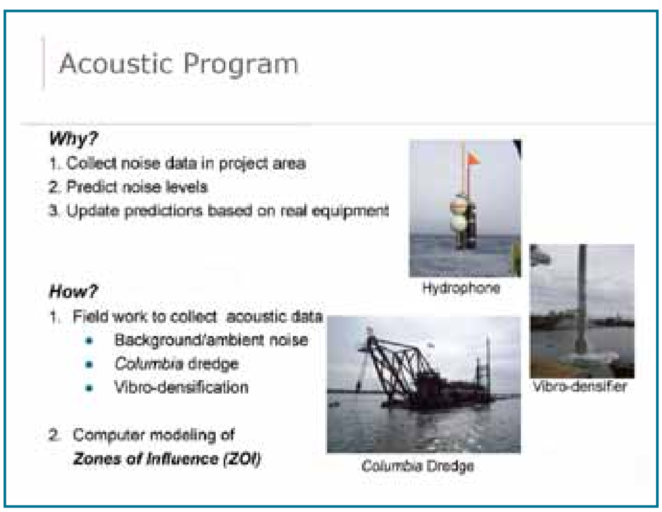

Figure 14: Port Metro Vancouver Acoustics Program, courtesy of Darrell Desjardin

The port has an acoustics program (Figure 14). Ambient pre-construction noise measurements have been undertaken, and zones of influence of noise on killer whales have been estimated. Fieldwork validates the modelling. Dredging noise is audible to less than 1,000 m and vibro densification is audible to less than 130 m. Behavioural disturbance is likely limited to within 1 km of the expansion, although some masking may take place at greater distances.

In 2012, the port will establish permanent land-based noise monitoring stations, which will be Web-based with a public interface. A hydrophone monitoring station will be deployed on the Fraser River. The port is also considering a program that would see incentives to vessels that mitigate noise by maintaining their propellers and hulls. The International Maritime Organization is also developing guidelines for ship-quieting technologies. Widespread port incentives would help to speed the rate at which industry adopts these technologies.

Emerging Marine Projects in B.C.

Ben Wheeler, Hemmera Consulting, Vancouver, B.C.

Using information collected through professional experience, and a quick search on CEAA and B.C.EAO databases, Wheeler provided a snapshot of emerging or proposed activities on the B.C. Coast (Table 1). industrial activity project proposals in the region is focused on oil and gas, port expansions, and renewable energy. The majority of proposed projects were for the North and Central Coast (NCC), particularly the port of Kitimat. Wheeler acknowledged that there are already a wide range of activities in addition to these projects that contribute to the underwater soundscape, such as whale watching, naval exercises, and construction activities.

TABLE 1: A summary of emerging or proposed activities on the B.C. Coast.

Project	Location	Description	Marine Activities
Kinder Morgan Westridge Terminal Expansion	Vancouver	Trans-mountain pipeline expansion / widening Second Narrows for Suezmax vessels	Dredging and shipping
YVR Fuel Delivery	Richmond	Marine transport of fuel to YVR	Construction and shipping
Container Capacity Improvement Program (PMV)	Delta	Capacity improvements at current Deltaport terminal	Construction and shipping
Canpotex	Burrard	Transportation of potash	Construction and shipping
Burnco Aggregate Mine	Howe Sound	Marine transport of aggregate	Construction and shipping
Canoe Pass Tidal Energy Project	Campbell River	Installation of two 250-kilowatt vertical-axis hydrokinetic turbines in a new pile-supported turbine support structure	Construction and operations
Misc.	West Coast Vancouver Island	Several conceptual wave energy projects	Construction and operations
Kitimat LNG	Kitimat (NCC)	Natural gas liquefaction and marine export terminal facilities	Construction and shipping
Shell LNG	Kitimat (NCC)	LNG marine terminal and export facilities	Construction and shipping
Douglas Channel LNG	Kitimat (NCC)	Convert SS Arctic into floating LNG plant	Construction and shipping
Methanex	Kitimat (NCC)	Condensate shipment in to Kitimat	Shipping
Enbridge Northern Gateway Pipeline	Kitimat (NCC)	Condensate import/bitumen export: double berth marine terminal	Construction and shipping
Pembina Pipeline	Kitimat (NCC)	Export of bitumen	Construction and shipping
Canpotex	Prince Rupert (NCC)	Transport of potash	Construction and shipping

TABLE 1: A summary of emerging or proposed activities on the B.C. Coast (continued)

Project	Location	Description	Marine Activities
BHP	Prince Rupert (NCC)	Transport of potash	Construction and shipping
Kitsault Mine	Alice Arm (NCC)	Marine transport of molybendum	Shipping
NaiKun Wind Farm	Hecate Strait (NCC)	Offshore wind energy project with up to 116 turbines	Construction and operations
Fairview Phase II	Prince Rupert (NCC)	Expansion of existing container-handling facility	Construction and shipping
Sandhill Marine Terminal	Kitimat (NCC)	Deep-sea marine terminal with associated shipping of aggregate to Californian and Hawaiian markets	Construction and shipping
Raven Coal	Port Alberni	Mining of coal and shipment from Port Alberni	Construction and shipping

PRESENTATIONS DAY 2

IV – NOISE MAPPING

The NOAA Underwater Sound Field Mapping Working Group: Developing Geospatial Tools to Inform Management of Cumulative Impacts on Marine Mammals

Leila Hatch, Stellwagen Bank Marine Sanctuary, NOAA, Mass.

The number of noise sources in the ocean is increasing, reducing the acoustic space available to marine animals. Management of these sources currently tends to be done at the local level, with the majority of concern focused on impacts to marine mammals. Future noise management needs to consider the cumulative footprints from multiple source types, and on ecologically relevant scales (spatially and temporally). It should address chronic lower-intensity sources, not just high-intensity transient ones. Ambient noise variability should be incorporated, and the impacts on a variety of marine animals and their habitats should be emphasized. In January 2010, NOAA scientists sent a letter to the White House committing the agency to improving its program of underwater noise management. Six months later, President Obama announced the first-ever U.S. National Ocean Policy, which coordinated national management of the oceans, and in January 2011, NOAA formed the Underwater Sound Field Mapping Working Group (SFWG) to address the need to map the temporal, spatial, and spectral characteristics of underwater noise.

The goals of the SFWG are to inform coastal and marine spatial planning processes, and to integrate cetacean distribution and density mapping to improve the characterization and management of cumulative noise impacts on marine life. To date, the group has completed a number of noise modelling exercises using open-source code that will soon be publicly accessible:

- The annual noise contributions from merchant shipping and seismic surveys to low-frequency (50 Hz) noise in the Atlantic.
- The seasonal noise contributions from seismic surveys in the Gulf of Mexico and in the Arctic.
- The noise associated with the construction of an offshore wind facility off the coast of New England.
- The decommissioning of an oil rig in the Gulf of Mexico using underwater explosives.
- The predicted noise levels of offshore oil rig service vessels in the Gulf of Mexico.

The results of these exercises have been submitted for publication. The model itself can be applied to other areas, because it is highly modular, and as such, is a very flexible assessment tool. The next step will be to integrate the model results with cetacean distribution and density mapping products. Hatch emphasized that finding marine mammals in areas with intense underwater noise is not an indication that they are unaffected by underwater noise, but that they may be reluctant or unable to leave the area owing to foraging or other needs. In May 2012, a symposium is planned that will involve scientists, environmental non-governmental organizations, industries, federal agencies, and conservation managers to discuss the implications of these results for ocean planning processes.

Modelling Cumulative Shipping Noise in the B.C. Exclusive Economic Zone

Christine Erbe,[1] Alex MacGillivray,[2] and Rob Williams,[3] [1]Director of the Centre for Marine Science and Technology, Curtin University, Perth, Western Australia, [2]JASCO Applied Sciences, Canada, [3]Sea Mammal Research Unit, University of St. Andrews, Scotland.

Commercial shipping is one of the most important global contributors to underwater anthropogenic noise. Erbe worked with collaborators at Dalhousie University in Halifax to compile all 2008 shipping data (8,766 hours) for the entire B.C. Coast. Vessels ranged in length from less than10 m to less than100 m, although records were generally biased toward larger vessels that are required to report their locations to the Coast Guard. The total number of traffic hours was 27,752. A matrix of vessel hours within a 5-km-by-5-km grid was used, and vessels were grouped into five length classes. Ships 100 m and longer were considered as one length class because vessel noise levels do not increase past a certain length. Source spectrum levels were assigned to each vessel class based on a literature review, the authors' own recordings, and published ship noise models. Geometric spreading and volume absorption was accounted for in transmission loss. Received levels were computed by integrating over time, and over all vessels within a 100-km radius.

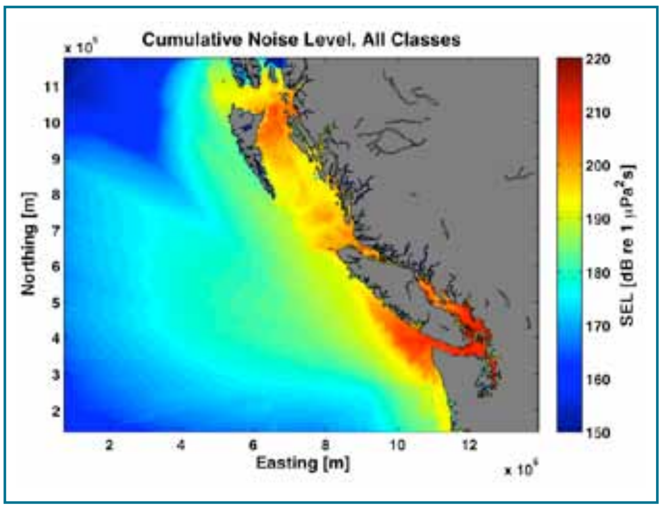

Figure 15: Cumulative annual shipping noise for 2008 on the B.C. coast, courtesy of Christine Erbe

The resulting map was an acoustic "picture" of annual shipping noise over the entire coast. Not surprisingly, areas around southern Vancouver Island were strongly ensonified, in large part due to the volume of shipping traffic in and out of the ports of Seattle and Vancouver. However, it was surprising to see relatively high noise energy in the northern portions of Hecate Strait (Figure 15).

The authors undertook a sensitivity analysis to determine the uncertainty of the map as a function of several factors (bathymetry, geology, and water parameters). Bathymetry was the main factor affecting received levels at frequencies below 200 Hz. During the winter, a mild surface duct in the water column reduced transmission loss and allowed energy at higher frequencies to travel farther. During the summer months, the water was downward-refracting, which increased transmission loss and reduced the distance that higher frequencies travelled. Soft sediments absorbed more sound energy than did bedrock. Errors in estimating transmission loss were assessed by comparison to field measurements made in northern B.C. Errors in source level were estimated from the literature. The standard deviation of the cumulative sound exposure level in the grid cells of the highest ship traffic was estimated to be 9 dB.

Recommendations for future work include:

- resolving ocean noise on a finer scale, particularly in fjords and in critical habitat areas
- using more sophisticated sound propagation models, and over a wider range of frequencies
- quantitatively forecasting and hindcasting to assess how trends in shipping may translate to trends in ocean noise
- creating layers for other noise sources such as construction (dredging and pile driving in particular), seismic surveys, and military activities
- overlaying distribution maps of vulnerable species to evaluate the impacts of anthropogenic noise on habitat.

Many questions remain to be answered:

- What are the biological effects of noise exposure?
- How do these vary by species?
- How do the effects of noise interact with those of other stressors?
- How do we manage stressors/habitats?

During the question period, Erbe acknowledged that deeper oceanic waters beyond the west coast likely contribute a significant proportion of low-frequency noise to the nearshore environment, and this has not been quantified. As well, 2008 was a period of significant economic downturn, and shipping was reduced relative to other years.

V – CASE STUDIES

Integrating Underwater Noise Within Coastal and Marine Spatial Planning Frameworks: Lessons from Stellwagen Bank National Marine Sanctuary

Leila Hatch,[1] Christopher Clark,[2] Sofie VanParijs,[3] DImitri Ponirakis,[2] and Adam Frankel,[4] [1]NOAA SMNMS, [2]Cornell University, N.Y. [3]NOAA NEFSC, and [4]Marine Acoustics Inc.

The marine sanctuary in the Stellwagen Bank was developed based on information collected over decades through systematic surveys and opportunistic marine mammal sighting records. It is also an area with a high density of maritime activities, from whale watching to commercial fishing and shipping. Hatch and colleagues obtained 150 million records of ship traffic for the area from 2006, with a resolution as high as every two seconds. They also collected over three years of continuous acoustic data (sampled at 2 kHz) through the use of pop-up recorders. Multi-beam sonars were used to acquire depth and sediment information, and CTD casts were used to measure temperature and salinity, all factors that influence the propagation of sound in the marine environment. Underwater speakers were used to compare actual versus modelled transmission loss. Wind data and large vessel traffic records were used to characterize ambient noise, and for some vessels it was possible to develop ship-noise signatures. It is well known that noise does not travel evenly in all directions.

Calls of right whales were also detected and localized using the hydrophone array. This information, combined with visual sighting records, revealed locations of concentrations of animals, which was then used to identify areas where right whales might be most vulnerable to shipping traffic and noise. This information was animated and showed a time series of vocalizing right whales and ships transiting the area. Ultimately, shipping corridors in the sanctuary were shifted to reduce the risk of ship strikes and to decrease the impacts of vessel noise on this endangered population.

How the Gully MPA Is managed for Underwater Noise

Lindy Weilgart, Okeanos Foundation and Dalhousie University, Halifax, N.S.

The Gully is the largest submarine canyon in eastern North America and is located 200 km southeast of Nova Scotia near Sable Island. It is 65 km long, 15 km wide and 2,500 m deep at the mouth. It is critical habitat for an endangered population of 130 northern bottlenose whales that reside in the area year-round. In 1994, the area was declared a whale sanctuary, and by 1998, a 10-km buffer zone excluding seismic activity was recommended. In 2004, the Gully was established as a marine protected area (MPA), and in 2010, it was declared critical habitat under the Species at Risk Act for the northern bottlenose whales, with three areas defined for management purposes. One area allowed no extraction of any resources, a second area allowed no commercial net or mobile fishing gear, and the third area allowed commercial activities on a case-by-case basis (Figure 16). Exceptions were made for government search and rescue, and enforcement and military vessels, so compliance by the military was voluntary. Scientific research is probably one of the biggest threats to the Gully, despite projects requiring approval through the environmental assessment process.

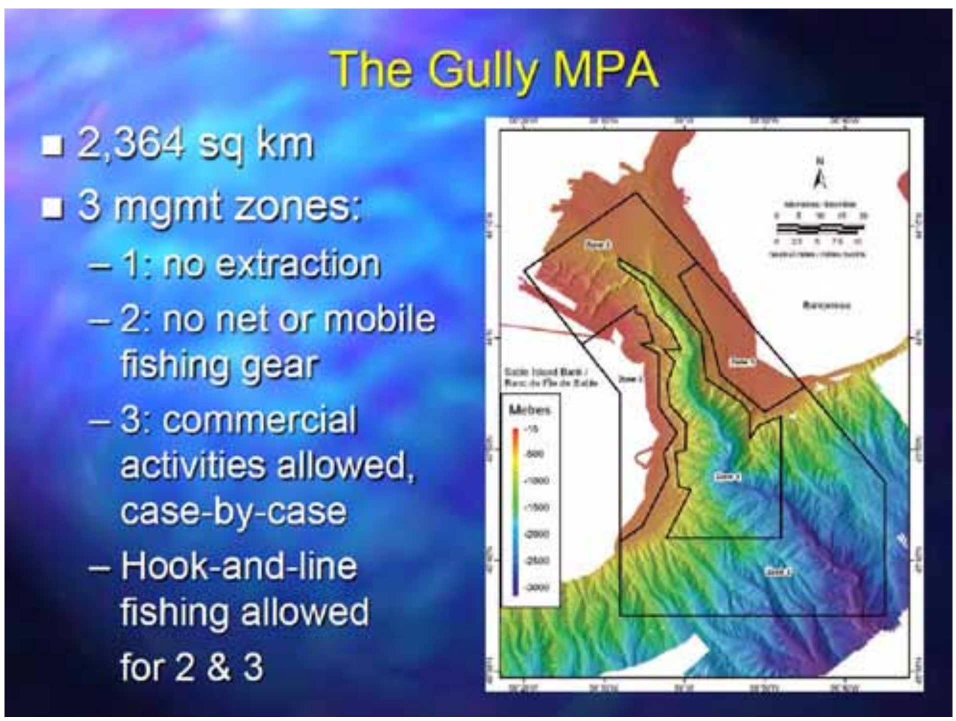

Figure 16: Management zones of the Sable Gully marine protected area, courtesy of Lindy Weilgart

Shipping traffic is not forbidden in the Gully, but Notice to Mariners asks for voluntary compliance to avoid the area or slow down and post a watch for whales. In order to have the area declared a Particularly Sensitive Sea Area (PSSA) or an Area to be Avoided (ATBA) through the International Maritime Organization, a risk analysis would have to be conducted. The MPA regulations do not expressly prohibit oil and gas activity in the area, but there are voluntary restrictions on both vessel and air traffic. The closest oil and gas activities are 35 km away. The regulations have a Vicinity Clause that applies to jurisdictions beyond the Gully. Activities that generate more than 140 dB rms in the Gully would require more mitigation and monitoring, and the clause is a potentially powerful legal tool for transboundary threats. The highest noise level measured in the Gully was 145 dB rms. There is still increased low-frequency background noise in the Gully. In order to manage for loud mid-frequency noise, an MPA would need to be 1,000 sq. km, and only 64 of 350 MPAs around the world meet this criterion (Hoyt, 2011). To manage for loud low-frequency noise, the MPA would need to be 10,000 sq. km. Only 20 of the world's MPAs meet this criterion.

Long-term passive acoustic monitoring is needed in MPAs to detect trends in noise, and in cetacean distribution and abundance. Noise may be correlated with ecosystem and population health. Monitoring would help in ensuring enforcement and compliance of human activities in the area. Noise monitoring to 50 kHz has been undertaken over the last few years.

There are some challenges to the Gully MPA. There is no provision in the Oceans Act or in MPA management plans for acoustic buffer zones, and there has been no test of the power of the Gully regulations. Weilgart suggests setting precautionary limits in advance of proposed activities to prevent potential harm.

Presentation Reference:
Hoyt, E. (2011). Marine protected areas for whales, dolphins and porpoises: A world handbook for cetacean habitat conservation and planning (2nd ed.). London: Earthscan.

Studies of Vessel Noise off Southern California

John Hildebrand, Scripps Institution of Oceanography, University of California, San Diego, Calif.

The Santa Barbara Channel is one of the entry points into the port of Long Beach, California, and is transited by approximately 18 ships per day. Hildebrand and colleagues deployed a calibrated High Frequency Acoustic Recording Package (HARP) to record sounds from 10 Hz to 100 kHz 3 km north of the northbound shipping lane for the purposes of measuring shipping noise. Using data from the Automatic Identification System (AIS), they monitored ship traffic in the channel (Figure 17). The majority of the vessels were cargo ships and tankers, and it was possible to quantify the received noise levels at the hydrophone to estimate ship source levels for different types of vessels. Although ships produce sounds to 360 kHz, the focus of this study was on sounds below 1 kHz. Bulk carriers produced more energy at slightly higher frequencies than did tankers or container ships, and all vessels were louder after they passed the hydrophone, due to propeller noise. Approximately 10–15 per cent of ships were noisier and had unusual spectra, suggesting damaged propellers, which would likely reduce fuel efficiency.

Underwater noise varied with ship speed, with faster vessels generally producing more noise. Hildebrand posed the question as to whether it would be better to travel at 20 knots and reduce the amount of time in the area, or reduce speed to 10 knots and spend twice as long in transit. He concluded that if there would be more than a 3-dB reduction in noise as a result of slowing down, then it would be worthwhile to do so.

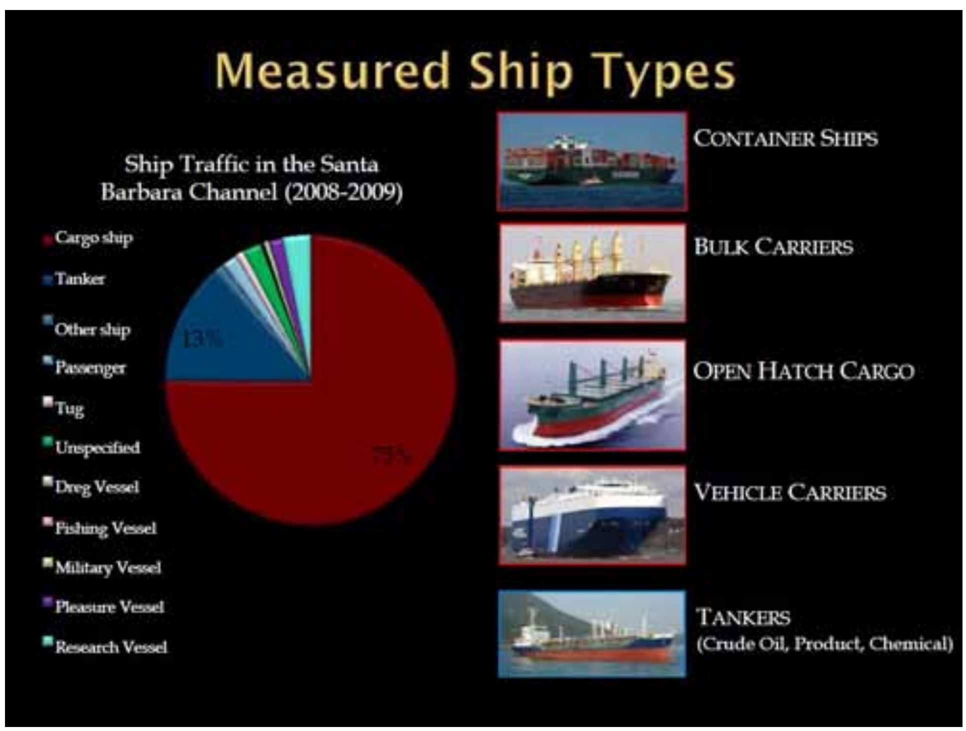

Figure 17: Ship types recorded in the Santa Barbra Channel, courtesy of John Hilderbrand

Ocean Observation and Sound in the Marine Environment: Toward an International Quiet Ocean Experiment

Ian Boyd[1] and Christine Erbe, [2], [1]Scottish Oceans Institute, University of St. Andrews, Scotland, and [2]Curtin University, Perth, Western Australia.*

In March 2010, at a meeting of those interested in the issue of underwater noise, a question was posed asking what would happen if you exposed animals to "quiet" rather than to noise. At present, most studies are done by adding noise to an already noisy environment and/or on noise-impacted animals. Yet there are no areas of the world's oceans that are not affected by human influence, and a large proportion (~40%) is strongly affected by multiple drivers, although there are still areas that are relatively quiet, particularly near the poles (Halpern et al., 2008). Shipping is a major source of noise in the ocean. Since the 1960s, the amount of cargo transported by sea has increased by more than 3.5 times, but the number of ships has only increased by 2.7 times, suggesting that ships have become larger.

The International Quiet Ocean Experiment (IQOE) was described in Boyd et al. (2011). The experiment recognized the problem that humans continue to add sounds to the ocean that completely overlap the full range of sounds that animals use. We know that currently there is evidence of increasing anthropogenic sound, and that in some cases there are measureable biological effects. There is a high degree of uncertainty, but worst-case scenarios have serious implications for the health of the oceans. This should lead to a precautionary approach within legislation. The goals of the IQOE are to use a multi-stakeholder approach, to ensure that sound measurement is an integral part of ocean observing systems, and to protect vulnerable species through mitigation to minimize economic impacts. An example outcome of the project will be a world map of anthropogenic ocean sound (not just shipping). Ocean observing systems such as VENUS, NEPTUNE, and Listen to the Deep are steps toward this world map. In Australia, inexpensive acoustic recorders are being used to allow citizen scientists to contribute recordings to www.AquaticAcousticArchive.com. The IQOE study is in the early planning stages and is due to publish its science plan soon, and hopes to establish a "Year of the Quiet Ocean" within six years.

Presentation References:
Boyd, I.L., Frisk, G., Urban, E., Tyack, P.L., Ausubel, J., Seeyave, S.,…Shinke, T. (2011). An international quiet ocean experiment. Oceanography, 24(2), 174–181.
Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C.,…Watson, R. (2008). A global map of human impact on marine ecosystems. Science, 319(5865), 948–952.

VI – INCORPORATING NOISE INTO FUTURE PLANNING

Rapid Evolution: Progress and Trends in Ocean Noise Mitigation

Michael Jasny, Senior Policy Analyst, National Resources Defense Council.

Interest in ocean noise mitigation began in the early 1990s with the Acoustic Thermometry of Ocean Climate (ATOC) experiments. Concern was expressed regarding the effects on marine mammals of broadcasting low-frequency sound (75 Hz) into deep-water sound channels, where it would propagate for extremely long distances. A few years later, a number of stranding events of beaked whales that were associated with military sonars increased concern about the effects of ocean noise. Mitigation became focused on reducing near-field exposures through safety zones and ramp-ups, as well as on visual monitoring. Since then, there has been a gradual shift in concerns from transient sound sources to more chronic noise and its cumulative impacts. Complementary approaches are emerging in marine conservation for acoustically quietened areas (through marine spatial planning, and marine protected areas). There has also been increased investment by industry into noise reduction and alternative technologies, although this does not replace near-field mitigation.

Mitigation through safety zones and ramp-ups is somewhat problematic. There is considerable variation in protocols used around the world, and it is known that not all animals will abandon important habitat areas in response to increasing noise. Implementing exclusion zones around hot spots was initially done on a project-by-project basis, but there is a growing movement toward programmatic assessments to consider sector-wide exclusions and, in some cases, marine protected areas (Figure 18). Predictive habitat modelling is an essential component of programmatic assessment.

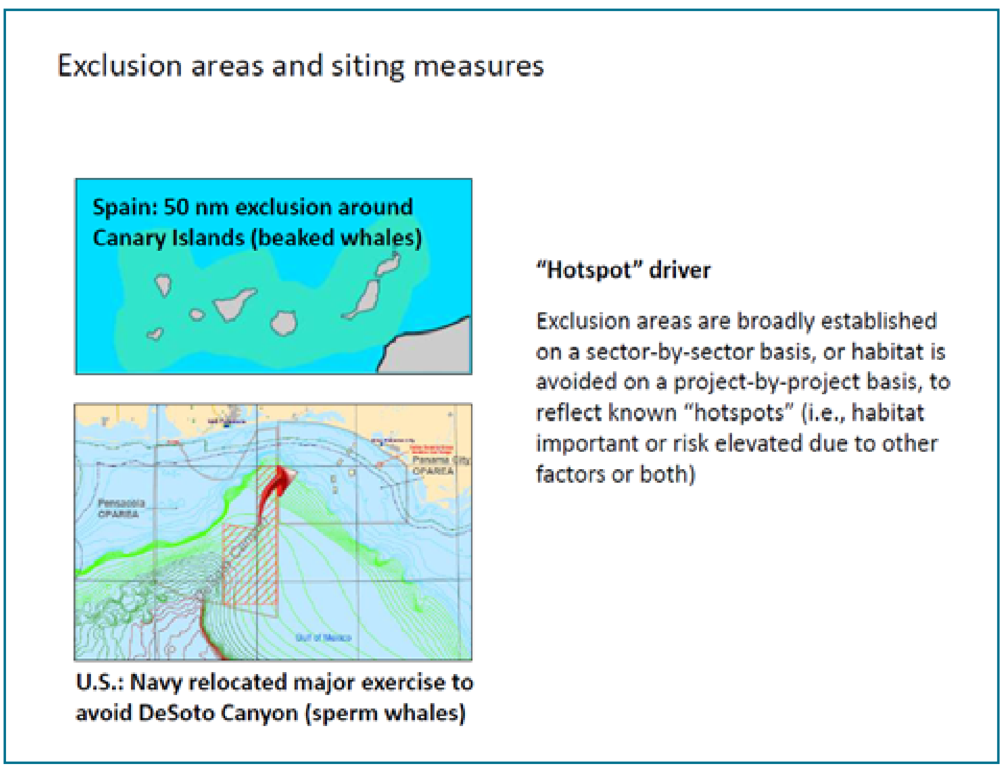

Figure 18: Examples of an exclusion around a hotspot, courtesy of Michael Jasny

Mitigation from ship quieting is also an important tool to reduce ocean noise. It is widely recognized that the largest source of ship noise is propeller cavitation, which also increases fuel consumption, air emissions, and maintenance costs. Jasny cited a previous Okeanos workshop statement on ocean noise, in which participants called for a reduction in the contributions of shipping to ambient noise by 3 dB in 10 years and by 10 dB in 30 years, through the use of ship-quieting technologies. This statement was subsequently endorsed by the International Whaling Commission, Scientific Committee. Recent observations suggest that even relatively small improvements in ship quieting could have significant impacts on ocean noise. If 16 per cent of the loudest vessels reduced their noise by 6 dB, this would result in a 60 per cent reduction in the ensonified area. Merchant ships show a range of 40 dB between the quietest and the noisiest vessels, suggesting that there is also room for improvement in ship quieting. Recent assessments suggest that it is feasible to reduce cavitation by 6–10 dB, although more reductions would require further research. The costs of increasing the efficiency with which a ship hull moves through the water is insignificant relative to the fuel savings that would be incurred. The International Maritime Organization recognizes the importance and benefits of vessel-quieting technologies, particularly in propulsion, but also in hull design, on-board machinery, changes in vessel speed and loading, and in maintenance schedules. Other mechanisms for ship quieting include regional- and country-specific requirements for quieting, as well as financial incentives (e.g., tax reductions, fuel efficiency, green certification, and incentive-based regulations).

Alternatives to using air guns for seismic exploration are being developed, and may be commercially available within the next three to five years. Marine vibroseis is particularly promising. Mitigation for pile driving includes vibratory piledrivers, bubble curtains, cushion blocks, cofferdams, and changes in pile design.

In summary, best practices for ocean noise mitigation and management:

- consists of operational measures to reduce near-field risk and (increasingly) habitat-based mitigation, with technology-based mitigation emerging as critical for several major noise sources;
- are often project-based, but increasingly rely on programmatic processes such as EIAs that better allow for non-operational mitigation and management of cumulative impacts; and
- are generally sector-specific, but possibly evolving toward synthetic, multi-sector regional and population management.

An Overview of DND Military Sonar Policy and Procedures*

Kathy Heise, Cetacean Research Lab, Vancouver Aquarium, Vancouver, B.C.

There are a number of military exercise areas off the west coast of British Columbia. Naval personnel are trained to identify and record marine mammal sightings and follow MARCORD 46-13 Marine Mammal Mitigation Procedures during all exercises. When operating in other jurisdictions, they follow whichever country's environmental protection protocols are most stringent.

DND has adopted a sound-pressure level criteria of 160 dB re 1 µPa for use in defining the boundaries of Mitigation Avoidance Zones (MAZs) when employing active sonar systems on board ships and aircraft. Mitigation zones for the most powerful AN/SQS 510 sonar is 4,000 m, 1,000 m for the Thomson 2024 and the AQS-502, and 300 m for the DICASS buoys. Prior to operations, aerial surveys are conducted for marine mammals when possible, and visual and acoustic watches are maintained throughout the exercise. At least one hour before an exercise, bathythermographs are launched to calculate sound velocity profiles for comparison with acoustic models. Thirty minutes prior to activating sonar systems, a watch is maintained on all radar and passive sonar systems. Ramp-up procedures are implemented prior to commencing operation with the SQS 510 sonar.

If a marine mammal is detected within the MAZ, active sonar transmissions are suspended until the animal leaves the area, and this information is shared with all participants in the exercise. The navy is working continually to improve its operational practices and procedures.

*Note that this presentation was based on one that Duane Freeman (DND) shared with the Resident Killer Whale Recovery Team on May 15, 2007.

DFO Science and Policy on Ocean Noise

Mike Stoneman and Heather Danielson, Fisheries and Oceans Canada, Ottawa, Ont.

The Department of Fisheries and Oceans has achieved a number of goals under the Oceans Act. These include the creation of five large ocean management areas (LOMAs), the identification of ecologically and biologically significant areas (EBSAs), eight designated marine protected areas (MPAs), and the development of integrated ocean management plans, collaborative processes to resolve conflicts, and the statement of Canadian practice with respect to the mitigation of seismic sound. Policy targets can be both economic and environmental. As DFO moves forward, it wants to maintain or increase marine environment quality (MEQ) objectives by incorporating the issue of underwater noise into the framework, and to continue working to achieve a network of MPAs.

Noise disturbance has been identified as a potential stressor for the recent validation of pathways of effects models for marine renewable energy, and shipping noise will merit further attention in 2012–13, including the development of an internal science working group. DFO will continue to work with others to identify key ocean noise issues, and much of this work is being driven by the increased activity in Canada's Arctic. For example, the Baffinland Iron Ore Mine will be raising anthropogenic underwater noise levels significantly, particularly with the use of icebreaking ore carriers that will be operating on a daily basis.

Ocean noise is part of MEQ, though there is no specific ocean noise MEQ regulation or standard under Canada's Oceans Act. Managing ocean noise is an objective in four east coast recovery plans under the Species at Risk Act (SARA), and one on the west coast. Transport Canada is also linking with the International Maritime Organization as it moves forward on the issue of underwater noise. Although slowly growing on the federal government's radar, more attention would certainly help to raise the profile of underwater noise.

BREAKOUT GROUPS

Report on the Hydrophone Networks/Calibration Working Group (Breakfast Meeting)

Ross Chapman, University of Victoria, Victoria, B.C.

A small breakout meeting was held over breakfast on February 1, 2012. Participants were generally either from the academic community, or from non-governmental organizations that were monitoring one or more hydrophones. There was a strong spirit of cooperation in the room. Participants recognized the unique contribution of those who have been collecting acoustic data for many years on non-calibrated hydrophones (particularly at OrcaLab, but also at Cetacealab) and the opportunity to collaborate with those who are either using calibrated hydrophones and autonomous systems and/or those with more technical expertise. With the current focus on development on the North and Central coasts (see Wheeler's presentation in this report), it would be especially timely to work toward back-calibrating some of this historical data, using a mobile calibration facility. Ocean Networks Canada (based out of the University of Victoria, "U Vic") may be able to broaden its mandate to take the lead on this. There was also consensus that as projects move forward, they should include at least one calibrated hydrophone in their network (e.g., The Heiltsuk hydrophone network), and HTI hydrophones (Mississippi) may be most appropriate. It was also agreed that the Working Group as a whole should develop protocols for noise monitoring, including calibration. Critically important details to record include the precise locations of the hydrophones and the gain levels that are set on the recorders. All records should be UTC time-stamped. Archiving of these data is also an important issue, and it may be possible to link into the work being done at the Orchive website that U Vic is maintaining (see earlier presentation by Paul Spong and Helena Symonds).

Report of the "Hot Spots" Breakout Group (Lunch Meeting)

Richard Dewey, University of Victoria, Victoria, B.C.

During lunch on May 1, a number of workshop participants gathered to discuss where to place hydrophones on the B.C. Coast to best monitor acoustic biological hot spots. High-priority locations put forward that are currently not being covered were Brooks Peninsula, off the west coast of Vancouver Island, and Money Point, on the Central Coast. Given the number of proposed projects for the North Coast, particularly Kitimat, Dixon Entrance and Hecate Strait would also be very good choices for placing future hydrophones to collect pre-development noise levels. Some of these systems could be autonomous if there are no networks in the area. At present, the majority of hydrophone recording locations are inshore, and the compelling need for offshore data was recognized, as well as in areas that have not yet been acoustically surveyed. All recordings should be year-round, and linked to year-round meteorological data. There was general agreement that seeing Erbe's shipping model produced on an annual basis, and covering a broader range of anthropogenic sources of noise, would be extremely worthwhile. It was also agreed that noise levels should be incorporated in the physical description of important and critical habitat for SARA-listed species. Incorporating acoustic features helps to give strength to descriptions of critical habitat.

Following the summary presentation, discussion in the room focused on avoiding the use of the term "noise budgets," and working instead toward "ocean noise field mapping." A budget implies that noise adds up to 100 per cent of the soundscape, whereas mapping more fully describes the ranges of noise that can be found in an area. A suggestion was also made that PAMGUARD in the U.K. has developed a standardized system of measurements that may be worth adopting in British Columbia.

ROUNDTABLE DISCUSSION: WHERE DO WE GO FROM HERE?

The final session of the Ocean Noise in Canada's Pacific Workshop was a group discussion in which participants drew on their collective knowledge as well as on the presentations and discussions of the previous two days to brainstorm how to incorporate ocean noise into future planning initiatives. There was clear recognition of the unique situation on the B.C. Coast: a considerable body of information relevant to characterizing the underwater soundscape exists already, and that given the scale of proposed industrial developments, this information could and should help inform planning processes.

The discussion focused on several key areas related to the region:

a) Existing acoustic data sources and making future data collection useful.

b) Further modelling anthropogenic noise and potential biological effects.

c) Approaches to mitigate anthropogenic noise.

d) Bringing ocean noise into marine planning and policy.

a) Existing acoustic data sources and making future data collection useful

While acknowledging the unique, long-term data sets that exist that could be used to establish a baseline to characterize current levels of ocean noise, the conversation often returned to whether the non-calibrated datasets maintained by OrcaLab and Cetacealab could be back-calibrated to provide relative measures of ocean noise over time. There was interest in seeing this work done through various options that had been discussed in the hydrophone network breakout group. The calibrated datasets held by John Ford (using AURALs) and Rob Williams (using pop-ups) would also be useful in this regard. The results would provide a relative (not absolute) long-term measure of ocean noise (potentially on the scale of 10–40 years). In addition, existing calibrated datasets (including collections from JASCO around the NaiKun wind farm in Hecate Strait) should be used in constructing the current baseline of noise for parts of the coast.

Participants recognized the need for consistent protocols for both acoustic and marine mammal data collection, and for a technical working group or workshop to establish these protocols. A key issue that was repeatedly identified was that the metrics that are recorded must be broad and flexible, so that as parameters of interest change as we learn more about the effects of noise on marine life, these parameters can be extracted from the data and incorporated into models (i.e., do not just store spectra). The U.S. National Park Service protocols for recording ocean noise have done a good job of preserving as much of the original data as possible, and the protocols would merit further examination as this issue moves forward on the West Coast. As the Heiltsuk hydrophone network is moving forward quickly, and the Cetacealab network is expanding, it would be extremely useful to establish these protocols quickly.

It was also recognized that future recordings needed to include a UTC time stamp to allow comparisons across locations. As well, the storage and archiving of acoustic data is problematic, and if centralized, it is unlikely that the data could be streamed because of the sheer quantity of data; some level of synthesis would be necessary. Hydrophone coverage on the coast should be expanded, although the resources to do that were not identified.

b) Further modelling anthropogenic noise and potential biological effects

There was widespread agreement that the shipping noise model generated by Christine Erbe was an extremely useful and powerful tool to visually illustrate noise levels from activities. There are at least three important initiatives that could follow from this work that would be most helpful in informing planning processes and ongoing development proposals:

- Focus on developing finer-scale noise models in smaller geographic areas where there is more human activity or anticipated growth in activities. Such areas include the North Coast and Douglas Channel, Johnstone Strait, and the Southern Strait of Georgia. Such models could inform noise management for both existing and future activities.
- Depict projections of anthropogenic noise levels from the large number (20 or so) proposed industrial developments as iterative scenarios that show predicted cumulative noise exposures depending on the number and type of projects approved. These exercises could focus on the Kitimat–Douglas Channel area (7 project proposals), or other specific areas such as Vancouver Harbour (4 projects), or could incorporate all coast-wide proposals (depending on financial resources).
- Analyze and overlay noise map models with known information on biologically important areas and the distribution maps of vulnerable species to assess potential impacts of noise on marine life. Such analyses should also include assessment of masking for vocalizing species.

The results of these models would be highly informative and useful for managers, regulators, and decision-makers, as well as in public outreach. To some extent, it would be possible to ground truth the finer-scale models through acoustic data previously collected by John Ford and Rob Williams.

Ultimately, including other sources of anthropogenic noise such as military exercises, pile driving, and other construction noise into ocean noise models would help to better describe the underwater soundscape and its potential impacts on marine life. It was also recognized that development of mapping and planning tools such as the software being created by NOAA could further inform efforts in this region.

Throughout the two days, a number of needs regarding research and knowledge related to the biological impacts of noise were highlighted. Some of these included generally improving the understanding of the biological impacts on noise exposure, identifying species-specific vulnerabilities to noise, and better understanding the interaction of noise with other stressors.

c) Approaches to mitigate anthropogenic noise

Mitigation was discussed relatively briefly, but was recognized to be an important component of ocean noise management. There is a desire to use models and/or data to identify acoustically quiet areas and keep them quiet, and to identify noisy areas and make them quieter. Regulatory tools such as establishing noise standards for MEQ were seen to be an important initiative, although the political will to move this forward will require significant outreach to and education of managers and decision-makers. The identification of acoustic refuges was also seen to be important, but based on experience with the Michael Bigg / Johnstone Strait Ecological Reserve, vessel exclusion zones are difficult to implement. Speed reduction zones and vessel separation schemes that direct traffic farther away from important habitat areas may be easier to introduce.

Non-regulatory incentives were also discussed, including engine-quietening technologies and changes to propeller design and maintenance that have the combined benefits of reducing noise and saving energy. Reduced port fees for acoustically quiet ships would also help motivate shippers to reduce their underwater noise profiles. There are some existing guidelines and for activities like seismic surveys. However, improving technologies for mitigating marine construction noise (such as pile driving) and alternatives to air guns for seismic exploration still need to be advanced.

d) Bringing ocean noise into marine planning and policy

It was widely recognized that there is a real need to engage with both the public and with policy-makers to increase their awareness of anthropogenic ocean noise and its potential impacts on marine life. It was repeatedly reiterated that noise data integrated with wildlife data, particularly for SARA-listed species, can be a powerfully informative tool. Noise can mask the ability of animals to use sound. This loss of “acoustic space” can be estimated from models, and needs to be translated into quantifiable effects in order to generate interest from policy-makers. Ocean noise maps are one method of doing this, but acoustic recordings can also be particularly meaningful.

There is also need to increase public awareness that areas on the coast aren’t as “acoustically pristine” as they might think, and that there is already significant anthropogenic noise, even in some parts of the North and Central coasts, as is evident in the cumulative noise energy map presented at the workshop (Erbe et al., 2012). At present, there are no models that consider the cumulative noise levels and effects of multiple projects and multiple stressors, but this would be a good direction to move toward. The desire for ecosystem-based approaches to noise management was also noted in this context with regard to managing noise and all other stressors.

There are areas of the coast that have not been well surveyed for noise and or biological data, particularly during winter months. Nonetheless, noise needs to be a component of the planning processes for MPAs, and, ultimately, there is a need for a network of acoustically quiet areas. There was recognition that MPA processes happen slowly—often over decades—yet other processes and proposals for industrialization and development are moving at a much more rapid pace. Efforts for noise mitigation must therefore proceed on a multi-pronged approach.

Toward a Workshop Statement

There was some enthusiasm in the room from non-government participants to develop a workshop statement or series of recommendations that would draw attention to the issue of underwater noise. During a previous Okeanos workshop, participants generated a workshop statement calling for a reduction in ocean noise from shipping of 3 dB within the next 10 years, and a 10-dB reduction in the next 30 years, which was endorsed by many of the non-government participants (see www.okeanos-foundation.org/assets/Uploads/StatmentofParticipants2.pdf). This recommendation has since been adopted by a number of other groups.

Participants made a number of suggestions that could be incorporated into a workshop statement. In no particular order they included:

- the need to consider ocean noise in environmental assessments and in marine planning processes;
- the need to reduce anthropogenic sources of noise through regulation and technology;
- the need to harmonize monitoring efforts;
- support for the implementation of port incentives (e.g., reduced fees for acoustically quietened ships);
- the need for planning processes to incorporate the cumulative effects of noise-generating projects, rather than on a project-by-project basis; and
- the need for planning processes to incorporate the cumulative effects of anthropogenic noise in concert with other stressors (physical disturbance, toxins, changes in food sources, etc.).

Given the time constraints at the discussion session, it was agreed that WWF-Canada would prepare a statement that incorporated these elements and circulate over email for acceptance.

ACTION ITEMS

The product of these roundtable discussions was a list of short- and longer-term actions for the ocean noise community in the region to embrace. The actions were driven by the expected massive increase in noise-generating activity on the West Coast by shipping (tanker traffic and container ships), industrial activity (port and renewable energy development) and other sources. The geographic focus was on the North and North Central coasts, where the greatest changes in anthropogenic noise are predicted to occur in the upcoming years.

SHORT-TERM ACTIONS (WITHIN SIX MONTHS)

1. **Develop an acoustic baseline** – Using existing collections of data, establish the currently known baseline levels of noise with a particular focus on the North Central Coast. Potential data sources identified include autonomous hydrophones (John Ford, DFO; Rob Williams, University of St. Andrews), data collection as part of the NaiKun Wind Energy project and JASCO research.

2. **Generate potential noise scenarios and analyze their biological effects** – (i) Generate potential noise scenarios based on the proposed activities for the North Coast. Some areas may require the development of models at finer scales (WWF-Canada to investigate). (ii) Prepare an analysis of the potential biological effects of the changes in noise levels on marine mammals and other sea life. The analysis would include such things as the masking of marine mammal communications by anthropogenic noise.

   Overlay biological distribution maps for marine mammals and other species on noise surfaces to illustrate future impacts.

3. **Provide technical advice for new hydrophone networks** – At least two new hydrophone networks are being set up — the Heiltsuk hydrophone network on the Central Coast and potential additions to Cetacealab on the North Coast (Ross Chapman of the University of Victoria and Richard Dewey of Ocean Networks Canada to provide technical input).

4. **Complete inventory of hydrophone systems** – There is a need to complete the mapping and database of all the hydrophone systems along the B.C. Coast (Scott Veirs, Beam Reach Marine Science and Sustainability School).

MEDIUM- TO LONG-TERM ACTIONS

1. **Integrate hydrophone networks** – Existing private hydrophone networks need to be calibrated and protocols need to be developed and standardized for measuring noise. This will make data collections and analyses comparable. Ocean Networks Canada is looking into getting support for coordination, including setting up a technical working group (Richard Dewey and Ross Chapman).
2. **Inform placement for future hydrophones** – Placement of future hydrophones should address gaps in data convergence and biological knowledge. This can be done after considering the distribution and density of marine mammals and by identifying where there are gaps in the hydrophone network. Recommendations are to be made based on the need for spatial and temporal marine mammal data, including, for example, Brooks Peninsula off the west coast of Vancouver Island, Money Point on the Central Coast, Dixon Entrance, and Hecate Strait.
3. **Provide management and policy recommendations for noise mitigation** – Investigate and research key policy and management approaches, including:
    - Designating quite areas and establishing a network of acoustically quiet areas (acoustic refuges).
    - Examining potential scenarios for traffic separation schemes such as have been utilized by Stellwagen Bank Marine Sanctuary on the Atlantic coast.
    - Recommending targets or goals for noise levels in certain biologically important areas.
    - Identifying measures where noise levels can be reduced or where noise levels can at least be prevented from increasing. Possible measures include port incentives, speed-limit reductions, and rerouting.
    - Developing MEQ objectives for anthropogenic noise.
    - Incorporating noise into environmental assessment processes, especially cumulative impacts of multiple projects.
4. **Provide input into regional MPA network planning** – Underwater sound and the impacts of anthropogenic noise on all marine life should be considered as part of the ongoing MPA network planning and current initiatives for MPA establishment and planning.

POST-WORKSHOP

Following the workshop, a statement was circulated via email, which the majority of participants agreed with:

> *Ocean noise is a growing concern and its impacts must be considered in the management and planning of current and future activities in the marine waters off British Columbia. There is a need to protect quiet areas and reduce anthropogenic noise levels, especially in ecologically important areas.*

As well, participants added additional data points to a map that Scott Veirs (www.orcasound.net) maintains, showing the locations of various hydrophones along the coast (Figure 19).

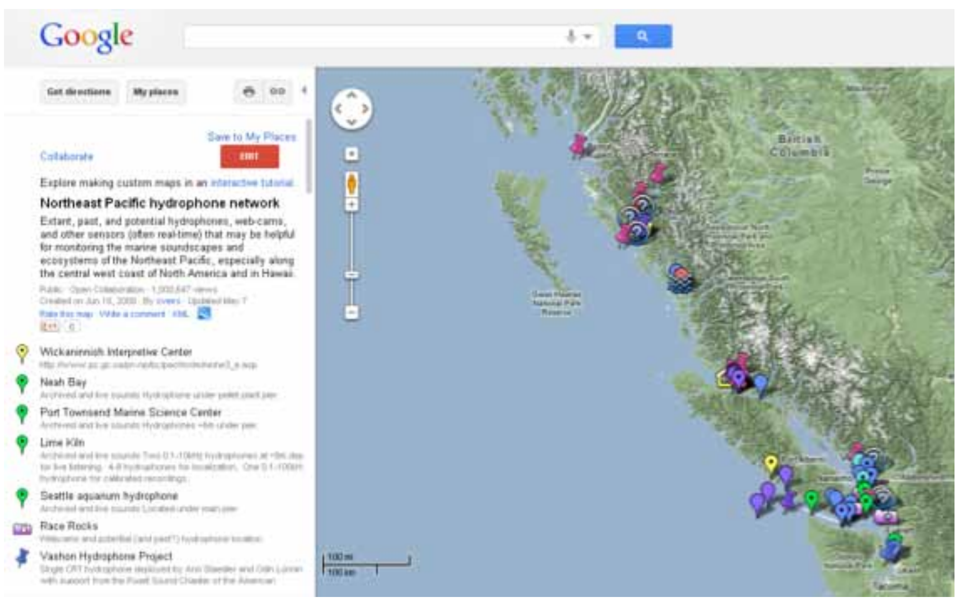

Figure 19: Hydrophone Networks and recording locations off the B.C. coast and adjacent U.S.A. waters, courtesy of www.orcasound.net

WWF POST-WORKSHOP SYNOPSIS

WWF-Canada will continue its work to better understand and improve management of ocean noise on Canada's Pacific. We will follow up on a number of the action items that emerged from this workshop, particularly those that relate to informing policy and management of ocean noise.

We have begun investigating further modelling and scenario development. Our collaboration with scientists and researchers in this field will grow, with an aim to facilitating the development and use of knowledge and products that can inform and advance noise management in the region.

We are working to ensure that anthropogenic ocean noise is a factor considered in bioregional marine protected area network planning in British Columbia, as well as in management planning for existing marine protected areas. We will continue to work to ensure that noise is identified as a potential threat to marine life, and that marine plans include steps to address this threat and effectively mitigate it. This is particularly related to our work on marine planning initiatives such as the Pacific North Coast Integrated Marine Planning Area plan (www.pncima.org), and the Marine Planning Partnership for the North Pacific Coast (http://mappocean.org).

Further, we will work with colleagues in Canada, the United States, and elsewhere to better understand the emerging range of tools and processes available to map ocean noise and mitigate its effects. In addition, we will continue to work with DFO on establishing standards for ocean noise, and will extend our outreach to Transport Canada to engage more fully in activities aimed at minimizing ship-source ocean noise by the International Maritime Organization. We will also continue to work with Port Metro Vancouver and Prince Rupert Port Authority, and support and encourage port procedures and incentives for quieting areas and ships.

One of the actions we took immediately following the workshop relates to ocean noise from military activities. Seven Canadian ENGOs including WWF, asked for a prohibition on military testing activities in killer whale critical habitat in the Salish Sea, because of concerns about underwater noise from military sonar and explosions after a bout of naval exercises. U.S. groups sent a similar letter to the U.S. secretary of the navy.

In addition, we will work with others to help promote greater public awareness of the issue of ocean noise, facilitate discussion, and implement other priority actions identified at the workshop. We are encouraged by the collaborations to be led by others that were spawned at this workshop, particularly on integrating hydrophone networks, protocols, and standards; making data collections consistent and comparable; and monitoring and addressing gaps in data collection. We will support, where possible, these and other efforts, including research that seeks to obtain a better understanding of potential impacts on non-marine mammal species such as fish and invertebrates.

We anticipate that within the next two years, as our work on ocean noise develops, there will be another opportunity to convene a second workshop to further many aspects related to anthropogenic ocean noise, and its effects and management that are relevant to this region, and to collectively move this agenda forward.

LIST OF WORKSHOP PARTICIPANTS

An asterisk (*) indicates participants who made presentations

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