Potential Acoustic Impacts of Vessel Traffic from the Trans Mountain Expansion Project on Southern Resident Killer Whales

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Scope of this report

This report is prepared in the context of the National Energy Board of Canada's review of the proposed Trans Mountain Expansion Project (the "Project"). The Project will carry diluted bitumen from the Alberta tar sands via a pipeline travelling from Edmonton, Alberta to the Westridge Marine Terminal in Burnaby, B.C. From there the oil will be transported by approximately 34 Aframax tankers per month through the Salish Sea to overseas markets. I have prepared this report for Raincoast Conservation Foundation who asked me to address six issues concerning the potential acoustic impacts and influences of vessel traffic from the Trans Mountain Expansion Project. The six issues of concern are:

1. Introduction to ocean noise and its significance for whales, including Southern Resident Killer Whales ("Southern Residents");

2. The amount of vessel noise in Southern Resident Killer Whale habitat from existing and proposed activities, including the Project;

3. Effects of vessel noise from existing and proposed activities, including the Project, on Southern Resident Killer Whale critical habitat;

4. Behavioral responses of whales, and particularly Southern Resident Killer Whales, to vessel noise from existing and proposed activities, including the Project;

5. Trans Mountain's assessment of acoustic impacts in Volumes 8A and 8B of the Project Application; and

6. Potential mitigation measures and opinion as to their efficacy.

Materials Relied upon

The documents consulted while preparing this report included Volumes 8A and 8B of the Project Application; numerous scientific papers on marine acoustics, marine mammal bioacoustics, and marine mammal responses to noises and sounds from anthropogenic sources; numerous reports in the non-peer reviewed literature on the matter of predicting, estimating and assessing the impacts and effects of anthropogenic sounds on marine mammals: for example, Interagency Ocean Policy Task Force (IOPTF, 2009), and National Research Council of the U. S. National Academies (NRC, 2000); as well as U.S. statutes (U. S. Endangered Species Act, 1973; U. S. Marine Mammal Protection Act, 1972) as points of reference related to the Project's Environmental and Socio-economic Assessment (ESA).

About the author

Dr. Christopher W. Clark is recognized as a world-class subject matter expert in marine mammal acoustics, with particular expertise in the quantitative evaluation of acute acoustic impacts and chronic acoustic influences from individual and cumulative human activities on marine mammals. He has pioneered methods for mapping and quantifying the spatial and temporal scales over which such impacts and influences occur. He has championed the concepts of noise budget, acoustic space, acoustic ecology and acoustic habitat and has been a leader in the development of analytical paradigms by which to measure the estimated costs to marine mammals from the loss of biologically important, acoustically mediated opportunities.

Dr. Clark is the Imogene Powers Johnson Senior Scientist in the Bioacoustics Research Program at the Cornell Laboratory of Ornithology and in the Department of Neurobiology and Behavior at Cornell University, Ithaca, New York. He was the founding Director of the Bioacoustics Research Program at the Cornell Laboratory of Ornithology and served as its director from 1987-2013. His educational background and professional experience are described in greater detail in his curriculum vitae, which is attached as appendix A to this report.

1. Introduction to ocean noise and its significance for whales, including Southern Resident Killer Whales ("Southern Residents")

Sound is as important to whales as vision is to humans. This statement is particularly true for killer whales, which send and receive acoustic signals to obtain most of their knowledge about other killer whales and their environment. Southern resident killer whales produce and listen to sounds in order to establish and maintain critical life functions: to navigate, find and select mates, maintain their social network, and locate and capture prey (especially Chinook salmon).

The scientific procedure for estimating and predicting biological impact from noise exposure has been based traditionally on the dose-response paradigm (see, for example, Southall, 2007). This paradigm assumes that the extent of the biological impact/effect can be predicted by the sound level at the animal. The Project Application applies this paradigm (see JASCO report: "*Supplemental Underwater Noise Modelling for Trans Mountain Expansion Project*"). The most recent and best available science now shows that in reality this assumption only applies to very rare situations when the animal is very close to the sound source and the received sound level is very high (e.g., >160-180 decibels relative to a sound pressure of 1 micro-Pascal, the standard decibel reference for in-water sounds), and that instead behavioural responses to elevated noise levels are primarily influenced by context (e.g. what animals are doing, where they are, who they are with, the time of year; see (Ellison, 2011). The JASCO report only references context as a factor, but does not consider context in its modeling exercise. In addition, elevated noise levels from human activities hinder the opportunities for animals (including killer whales) to acquire, broadcast and share acoustic information by reducing the received level of the sound that the killer whale is attempting to hear compared with the background noise level while the animal is listening[1]. This reduces the range out to which an animal can detect and recognize

[1] The relationship between the received level of the sound that the animals is attempting to hear compared to the ambient noise level as the animal is listening is referred to as the signal-to-noise ratio (SNR).

sounds of biological importance, which reduces the whale's acoustic space (i.e., their acoustic habitat) on which they depend for survival (see Clark, 2009; Hatch, 2012; Williams, 2014).

Southern resident killer whales are listed as endangered under Canada's Species at Risk Act. The area in Salish Sea portion of the tanker route is identified as critical habitat necessary for the survival and recovery of the Southern Residents. Ocean noise is named as one of the key threats hindering their recovery, along with chemical contaminants and reduced availability of salmon and in particular Chinook salmon (Fisheries and Oceans Canada, 2011). These threats may work in concert. Chinook stocks are at low levels of abundance compared with historic, pre-industrial numbers. When the ocean gets noisier, this makes it harder for whales to find scarce prey. When prey is scarce, whales start burning their stored fat to meet energetic demands. Contaminants are stored in blubber, so chemicals that may have been harmless when stored in fat become metabolized and can cause health problems. The cumulative impact of all of these multiple stressors has been poorly studied in killer whales, but we know from other species that animals under prolonged physiological stress may have reduced immune system function (i.e. they are unable to fight off pathogens that a healthy whale could easily fight), reduced ability for females to become pregnant, reduced survival of calves, and early death for adults. We also know that in at least one endangered whale species, the North Atlantic right whale, that there is a link between noise level and stress related hormone metabolites (glucocorticoids) (Rolland, 2012).

In summary, the Project will definitely increase noise levels in the region's marine acoustic environment. It is encouraging that the Application Volume 8A (sections 4.3.7.6.1, 4.3.15, 4.4.5.3.1, and 6.0) recognizes the significance of the Project-related effects on southern resident killer whales.

2. Vessel noise in Southern Resident Killer Whale habitat from existing and proposed activities, including the Project

The Salish Sea is already a noisy place. A recent prediction of sound levels from existing shipping activities throughout Canada's Pacific waters found that the entire proposed Project area presently experiences noise levels that are above a threshold used in Europe to define "favourable conservation status" of marine habitats (Erbe, 2012). Canada has not established a quantitative policy target for how noisy or how quiet a critical habitat should be, but based on the indicators used in the European Union's Marine Strategy Framework Directive, noise levels in the area that would be acoustically influenced by the proposed Project are already high and above the threshold level that would deem the area to be considered in "good" status. From that perspective, conducting a model study to predict increased noise from Project activities is not necessary: the habitat is already too noisy, and any additional noise will exacerbate this situation.

Southern resident critical habitat includes a busy shipping lane serving the ports of Vancouver and Seattle. It also supports a large whale watching industry, composed of dozens of boats from

Canadian and U.S. ports that follow the whales for much of the day in the summer season. The area is also heavily used by commercial fishing vessels, tugs, tankers, ferries and recreational boats. A recent study estimated that, on average, southern residents are already losing 62% of their opportunities to communicate acoustically, and that level rises to a 97% loss of acoustic communication space during periods of busy ship traffic (Williams, 2014). The import of this finding is that present noise levels under busy ship traffic conditions are already so high that additional ship traffic will seem to have little impact on communication space, when in fact their additional noise could essentially eliminate even those few remaining opportunities for killer whales to communicate.

There is existing evidence demonstrating the importance of ecological context when assessing noise induced behavioral responses. Independent studies of killer whales found that boat traffic caused northern resident killer whales to reduce the time they spent feeding by 18% and southern resident killer whales to reduce the time they spent feeding by 25% (Williams, 2006; Lusseau, 2009). These scientific results have disturbing implications for a population that is already experiencing food limitation (Ford, 2010; Ward, 2009; Fisheries and Oceans Canada, 2011; Williams, 2011).

Empirical measurements of ambient sound levels (natural and anthropogenic) found that critical habitats for southern resident killer whales have the noisiest levels of all sites sampled along the BC mainland coast (Williams, 2014). The project's proposed activities will only increase noise levels in an already noisy environment as a result of the aggregate contributions of ongoing human activities. Given these existing high noise levels, a doubling of those activities will only appear to increase predicted sound levels by a few decibels. This is because the physical metrics by which changes in noise level are quantified are logarithmic and based on the ratio of a measured sound pressure or intensity to a standard reference level. Thus, if a new activity doubles the existing sound pressure (a 100% increase), the decibel level only increases by 6 dB. For example, if the median ambient noise level someplace in the Project area is already at 100 dB (compared to 72-78 dB in quiet areas, see (Williams, 2014), a doubling of the noise introduced by Project activities will only raise that level to 106 dB. Therefore, this 100% increase in noise from the Project to the existing environment that is already noisy will appear to be only a 6% increase in noise level (6 dB) and not representative of the potential impact that the Project activities could impose on the acoustic environment, in general, and the killer whale's acoustic habitat, specifically.

The Project Application's inclusion of the JASCO report is very helpful, but this dose-response paradigm does not complete the assessment of the actual ecological and population level risks to killer whales. These results need to place the Project's and all anthropogenic noise activity influences in a biological and ecological context relative to the natural acoustic environment before the introduction of anthropogenic noise (i.e. the pre-industry quiet ambient noise environment, which is most likely at least 10-20 dB lower than the present environment.) In fact, it is essential to apply this perspective, because the focus here is on the southern resident population that is already at risk. From an acoustic ecology perspective, one must assess the effects of the Project's proposed activities relative to the killer whale's acoustic habitat before and without any anthropogenic influences). Lastly, this acoustic ecology perspective must include the assessment of chronic effects from lost acoustic opportunities at both spatial and temporal influence and the duration of the higher ambient noise condition.

The authors of the Project Application note this issue of what to use as the basis for comparing Project noise when they state that: "[c]urrent levels of ambient background noise in the Marine RSA limit the zone of detectability of noise originating specifically from Project-related marine vessels, although the background itself may be made up of audible noise from numerous other vessels." (Application Volume 8A, page BA-312). As stated above, it is encouraging that the Application Volume 8A (sections 4.3.7.6.1, 4.3.15, 4.4.5.3.1, and 6.0) recognizes the significance of the Project-related effects on southern resident killer whales.

In summary, this Project will definitely increase noise levels in the southern resident killer whale's acoustic habitat. Given the expected long-term and large-scale effects of the Project's activities on that habitat, these effects need to be translated into population level and ecological level risks.

<u>3. Effects of vessel noise from existing and proposed activities, including the Project, on Southern Resident Killer Whale critical habitat</u>

It is difficult, but not impossible, to assess the risks from and ecological effects of chronic noise at a population or ecological level. There have been a number of recent scientific publications attempting to make progress in this direction. One of these, Hatch et al. (2012), was not cited in any of the applicant proposal materials, but seems particularly appropriate since it address the specific issue of chronic vessel noise impacts on an endangered species. This oversight is unfortunate since the application of the Hatch et al. (2012) paradigm would definitely apply to southern resident killer whales. Regarding the ecological context, the International Quiet Ocean Experiment (Boyd, 2011) outlines a method for comparing ecosystem indicators across a gradient of noise levels, or experimentally introducing or reducing noise in replicate sites in order to assess how marine communities are most likely affected. The Applicant should consider including some components proposed in this report.

Generally, one uses the term "site" or "area" to refer to spatial coordinates of a place, whereas "habitat" refers to that site or area as it is used or perceived by a particular species. Discussion on the effects of noise on SRKW critical habitat really comes down to effects on the killer whales themselves (point 4, below) or their prey. There is evidence that Chinook salmon can hear sound (Nedwell, 2004). In summer 2014, Inge van der Knaap, a graduate student, conducted a pilot study in the Broughton Archipelago (BC) to test behavioural responses of Chinook and pink salmon, Pacific herring, and yellowtail rockfish to boat noise. She found significant responses of all species to boat noise. The implication from this preliminary work is that killer whale prey species are changing their behaviors in response to vessel noise, which in turn could lead to a reduction in killer whale foraging efficiency. This is an example where the potential ecological effects have not been well studied and thus impose another level of uncertainty as to the long-term effects of increased vessel traffic noise.

There is ample evidence that vessel noise from existing activities degrades southern resident critical habitat by rendering it unfit for its intended use as a foraging area by southern residents (discussed below), It therefore follows that proposed Project activities would further degrade this southern resident critical habitat. In either case it is unclear when the line is crossed from habitat degradation and its resultant reduced ecological value to such a high level of degradation that the habitat's value is essentially lost.

A seemingly modest increase in predicted physical noise levels from Project activities on the acoustic environment are not representative of their potential biological and ecological impacts on southern resident acoustic habitat. From an acoustic ecology perspective, one must assess the cumulative effects of all the present and proposed activities relative to the killer whale's acoustic habitat prior to and without any other anthropogenic influence. When Project-specific noise activities are assessed relative to a naturally quiet environment, the predicted influence of these activities on the spatial and temporal features of the southern resident killer whale acoustic habitat would be considerable: for example, depending on season and behavioral context (e.g. breeding, foraging), communication space could decrease by 25-75%.

In summary, the Project will definitely increase noise levels in the southern resident killer whale's acoustic habitat, but the chronic influences of those increases on that population and the ecosystem upon which it depends have not been and cannot be adequately assessed with the methods used by this Project.

4. Behavioral responses of whales, and particularly Southern Resident Killer Whales, to vessel noise from existing and proposed activities, including the Project

Killer whales are acoustically sophisticated animals. They have extraordinary hearing capabilities and a complex acoustic repertoire. When a killer whale hears the sounds from a boat or ship, behavioral observations lead to the conclusion that the whale engages in a complex, cost-benefit analysis to determine whether the cost of responding to the vessel (e.g., lost feeding or mating opportunity, dissociation from pod, energetic cost of avoidance) outweighs the benefit (e.g., reduced possibility of temporary hearing loss or collision with vessel). This decision-making process takes place in an ecological context, and the outcome of this behavioral response is not predicted by noise level disturbance (Ellison, 2011). Two studies have shown that northern and southern resident killer whales are more likely to tolerate small boat traffic (i.e., show no immediately observable behavioral response) when the whales are engaged in travel behavior than when they are feeding (Williams, 2006; Lusseau, 2009). Whales will show stereotyped, zigzag evasive responses during carefully controlled experiments to single boats at different speeds and approach distances (Williams, 2002; Williams, 2002). These tactics do not work when several boats are following the whales simultaneously, and experiments have shown that the avoidance tactic that killer whales use around a few (1-3) boats is opposite to those used when many more (4-18) boats are approaching the whales simultaneously (Williams, 2007). This effect is not predicted by the dose-response paradigm as used in this Project's biological assessment (described in items 1 and 2, above).

Notwithstanding the complexity described above, we can draw general conclusions about behavioral responses. Generally, as whales receive increasingly higher levels of noise from a vessel, which occurs as it is approaching (a context), they are increasingly likely to respond to the vessel using avoidance behaviors (Williams, 2014). This vessel noise study considered audiogram-weighted and unweighted received sound levels as explanatory variables in statistical models of whale behavior. The study tested whether variability in whale behavior was better explained by noise levels weighted by the frequencies to which the whales are most sensitive, or if broadband noise level, which included low-frequencies, was a better predictor of whale response. The broadband noise level was selected as the better predictor. In practice, this means that it is not necessarily possible to apply the dose-response paradigm with frequency weighting to predict how killer whales will respond to broadband vessel noise or to moderate levels of high-frequency noise. The empirical evidence indicates that killer whales have a stronger response to broadband noise, which includes the low-frequency ship noise band, than mid-frequency noise, even though the whale's hearing is less sensitive to low frequencies than mid-frequencies. This behavioral response is not predicted using the analytical paradigm as applied in the JASCO models for this Project Application, and thus serves as another example in which the dose-response paradigm is not a reliable mechanism for estimating impact from vessel noise.

Calculating the true cost to whales as a result of behavioral responses is not trivial. Killer whales are highly efficient swimmers across a wide range of swimming speeds; so evasive tactics that require a whale to zigzag or increase its swimming speed in a modest way may carry trivial energetic costs to the whale (Williams, 2009). The issue of concern is the cumulative effect of repeated behavioral avoidance responses to high numbers of vessel encounters. Each time a whale has to disrupt what it is doing to respond to a vessel, it is replacing a critical life process (e.g., resting, feeding, mating) with "vigilance." Its attention is switched from engaging in a naturally beneficial activity to something that is an unnatural distraction. When the animal attends to the dynamics of the boat (i.e. where it is, where it is going, how fast it is going) relative to its position, the time engaged in that behavior is time lost to engage in a natural beneficial behavior. The best available science on this topic suggests that if vigilance requires time that would normally be spent traveling, the relative increase in energy needed to travel at higher speeds so as to cover the same distance are small (e.g., an approximately 3% increase (Williams, 2006). A greater concern arises when the time devoted to vigilance is causing the whales to interrupt feeding bouts, which causes killer whales to spend 18-25% less time feeding in the presence of boats than in their absence (Williams, 2006; Lusseau, 2009). This raises population-level, conservation concerns in a food-limited population.

In addition to behavioral responses, underwater noise from existing and the proposed Project activities will raise background (ambient) noise levels, which will make it more difficult for killer whales to successfully echolocate and detect scarce prey than under quiet(er) conditions.

Theoretical studies (Erbe, 2002) and empirical measurements with captive killer whales (Bain, 1994) have shown that vessel noise does actually mask a killer whale's ability to detect biologically meaningful sounds (e.g., calls of other whales; the echolocation signal reflecting off a Chinook salmon).

Empirical measurements of ambient sound levels (natural and anthropogenic) at 12 sites from Haro Strait to Dixon Entrance found that southern resident critical habitats have the noisiest levels of all sites sampled along the BC mainland coast (Williams, 2014). A simple way to translate these elevated noise levels into a biologically meaningful metric is the concept of "lost communication space" as defined and quantified in Clark et al. (2009) and Hatch et al. (2012). Williams et al. (2014) applied this analytical paradigm to model the range at which a killer whale call or echolocation click will propagate under noisy and quiet conditions. This requires subjective decisions to be made about: baseline (historical reference) levels that constitute "naturally quiet conditions"; the functional range out to which, and thus the communication space over which, a sound is used by whales under naturally quiet conditions; and whether whales compensate by changing their types and rates of sound production or by somehow increasing their acoustic attention. Given best available information, the authors found that under present-day, median noise level conditions in Haro Strait, killer whales lose 62% of their opportunities to communicate out to a range of 8 km, and this loss of communication space rises to 97% during busy traffic periods.

From the perspective of a southern resident killer whale, its present-day acoustic environment cannot get much louder than it is currently. If under present-day median noise conditions in Haro Strait whales are already losing 62% of their acoustic communication space (as calculated in Williams et al. 2014), this imposes a relatively extreme ecological cost on this population. If one accepts these present-day conditions as normal; that is, this situation is removed from the ecological reality, the assessment of the Project's ecological impact will appear to have marginal biological cost, when in fact that cost will be significantly underestimated. In contrast, when the aggregate exposure levels from existing and Project related sound sources are appropriately assessed relative to the naturally quiet noise levels to which the whales are adapted, the estimate loss of communication space will be greater than 62%.

Any adequate assessment of the excessive loss of acoustic habitat must also take into account other known stressors (i.e., chemical pollution, reduced prey, reduced mating opportunities among pods, and small southern resident population size). These multiple factors can interact synergistically. If noise makes it harder for whales to find fish, which are already scarce, then whales begin to live off their fat stores. This would cause whales to metabolize chemical pollutants stored in the blubber, which could then have negative effects on animal health and reproduction.

Collectively, repeated exposure to noise can cause stress in whales (Rolland, 2012).

If left unmitigated, repeated disturbance can cause population level consequences in marine mammals (New, 2014).

In summary, there is a reasonable likelihood of population level and ecological consequences for southern resident killer whales from Project related increases in vessel noise events and the chronic deterioration of the whales' acoustic habitat. The present evaluation of the Project's short-term and long-term activities does not adequately asses the Project's population level and ecological consequences.

5. Trans Mountain's assessment of acoustic impacts in Volumes 8A of the Project Application

In several cases where the Volumes 8A report had a subjective decision to make concerning how to model acoustic impacts, the report applies a model that cannot estimate the ecological impacts on critical activities such as communicating, navigating and foraging. It focuses on noise levels likely to cause injury, rather than, for example, the chronic effects of noise likely to reduce prey acquisition. It is now well understood both empirically and via models that the likelihood of an animal being exposed to noise levels high enough to cause injury is very small. In addition, whales are known to avoid areas in which they might be exposed to elevated noise levels (see Ellison et al. 2012), and they can have different behavioral responses depending on noise level (Blackwell et al. in press). The report's assessment does not adequately address the chronic effects that increased levels impose and the subsequent ecological cost to individuals and the population.

The report ignores best available science on the probability that vessel noise will elicit a behavioral response (Williams, 2014).

The report imposes the authors' assumption that the whales should respond to noise within the frequency band in which the whale's hearing is most sensitive. Because ship noise has most energy in the low-frequency band and killer whales are mid-frequency hearing specialists, this assumption underestimates the effects of noise on killer whales. This approach is not precautionary and does not take into account best available science. It ignores a body of literature showing that killer whales respond to low-frequency noise (e.g., fishing vessels, tug boats) by reducing the time spent feeding (Williams, 2006). It ignores a study that showed that broadband received levels from ships are better predictors of killer whale behavioral responses than levels that are weighted by hearing sensitivity (Williams, 2014), and a study indicating that killer whale responses to sonar did not support the use of audiogram-weighted received level over broadband received level (Miller, 2014). These points undermine the authors' claim that they were conservative when modelling whether the number of expected behavioral responses was negligible.

Notwithstanding this decision to downplay the impacts of low-frequency noise from ships, the JASCO supplemental report also ignored scientific evidence showing that often there is more energy from ship noise in the higher frequencies than the extrapolated values used in their models (Veirs, 2015; Hildebrand, 2006; Hermannsen, 2014). Ignoring the high-frequency energy is not precautionary.

Canada has not articulated a policy statement on chronic ocean noise from ships in the southern resident killer whale critical habitat in any quantitative terms (Williams, 2014), nor indeed for any Canadian species at risk (Weilgart, 2007). Despite this, the authors made an implicit policy decision that "no net increase" is a legitimate policy target, because they compared projected noise levels to present noise levels. This essentially tells regulators what their policy decision should be, and that the *status quo* (current noise level) is sufficient to protect critical habitat. Clearly, this is not at all appropriate, especially when an emerging body of research shows that the whales' acoustic environment has already been seriously affected by anthropogenic noise.

No attempt was made to estimate population-level consequences of noise to southern residents, although statistical tools are available to do so (National Research Council, 2005; New, 2014; Thomas, 2005; Thompson, 2013). Although the report does state that acoustic impacts are significant (see Application Volume 8A, sections 4.3.7.6.1, 4.3.15, 4.4.5.3.1, and 6.0), they attribute these impacts to the noise from present vessel traffic, not to noise from the proposed Project, thereby reaching a conclusion that noise from the proposed Project will have little to no impact. The authors and the proponents are asking readers to simply take their word that the effect sizes are negligible, when no attempt was made to model biological significance and population consequences of the project alone and relative to normally quiet, non-vessel noise levels.

Finally, the authors claim that they are using their "indicator species" as conservative proxies for broad taxonomic groups of marine mammals. This ignores a body of evidence that some species (e.g., harbour porpoise) show strong avoidance responses to pile-driving noise at extremely long ranges (e.g., >20km; (Tougaard, 2009)), a level of response that would not be predicted based on audition or a proxy species. The failure to include these key studies belies the statement that the acoustic section of the report is meant to be a conservative predictor of environmental effects.

In summary, the evaluation of the Project's short-term and long-term activities on the acoustic environment is subtly biased such that the Project's population level and ecological consequences are underestimated.

6. Potential mitigation measures and opinion as to their efficacy

Speed restrictions are known to reduce the likelihood of fatal collisions (Kraus et al. 2005) (Laist et al 2014) and vessel noise level (Kipple and Gabriele 2003), so implementation of a vessel speed restriction condition would most likely provide significant benefits to marine mammal populations in the Salish Sea. In this Application Volume 8B the entire assessment of risk from underwater noise is undermined by the proponent's own section on mitigation, which acknowledges that the applicant has no way to ensure compliance with speed restrictions placed on project-related tanker traffic (Application Volume 8B, p. 6.1).

a. "Underwater noise from vessel traffic has the potential to affect a marine mammal's ability to communicate with conspecifics, to detect prey and to avoid predators. These effects are of greatest concern for species with depressed population sizes, such as the southern resident killer whale. As a precautionary measure to reduce underwater noise generated by vessels and, in turn, reduce potential adverse effects on marine mammals, it was recommended that all Project-related tankers and tugs observe a maximum speed restriction while transiting within the Marine RSA. While Trans Mountain has little direct control over the operating practices of Project-related tankers or tugs, it was the professional judgment of the discipline expert that given the existing pressure on marine mammals this was the most practicable solution available at this time."

b. "Self-mitigation" – The authors presume that the animals can compensate for any increase in noise. For example, in Application Volume 8A, P 8A-319, the authors write: "Holt (2008) found that for every 1 dB increase in underwater noise, killer whales will attempt to compensate by increasing their vocalizations by 1 dB." Newer research by this team (Noren, 2013; Holt, 2015) has shown that this compensatory mechanism comes with an energetic cost. Compensating for a noisier environment may cost dolphins a 20-50% increase in the level of energy expended compared to over resting conditions.

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PRESENT POSITION
Imogene P. Johnson Senior Scientist, Bioacoustics Research Program, Cornell Lab,
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EDUCATION and EMPLOYMENT

Stony Brook University, Stony Brook, NY	B.Sc.	1972	Biology
Stony Brook University, Stony Brook, NY	B.E.	1972	Engineering
Stony Brook University, Stony Brook, NY	M.S.	1974	Electrical Engr.
Stony Brook University, Stony Brook, NY	Ph.D.	1980	Biology
The Rockefeller University, NY, NY	Post. Doc.	1981-83	Bio/Anim. Comm.
The Rockefeller University, NY, NY	Asst. Prof.	1983-87	Bio/Anim. Comm.
Cornell University, Ithaca, NY	Senior Sci.	1987-present	CLO and NB&B

PROFESSIONAL SOCIETIES
Acoustic Society of America Fellow
Animal Behavior Society
AAAS, IEEE
Explorers Club (FN85)
Society for Marine Mammalogy
Sigma Xi,
Tau Beta Pi

HONORS AND AWARDS
Member, Tau Beta Pi, 1969
President, Tau Beta Pi, Stony Brook Chapter, 1971-1972
National Fellow, Tau Beta Pi, 1972-1973
Biomedical Research Fellowship, 1978, 1979
NIMH Postdoctoral Fellow, 1981-1983
Fellow, Acoustic Society of America, 2000

PROFESSIONAL APPOINTMENTS
1983 - 1987 Assistant Professor, The Rockefeller University, New York, NY
1985 – 2010 U.S. Delegate to the International Whaling Commission Scientific Committee
1987 - 2013 Director Bioacoustics Research Program, The Cornell Lab of Ornithology
2013 - present Senior Scientist, Cornell Lab and Dept. of Neurobiology and Behavior, Cornell University

RECENT AND ONGOING RELEVANT RESEARCH

1996 – present-ongoing: Acoustic monitoring of large whale distributions, behaviors, and movements relative to environmental factors and man-made activities using Navy IUSS assets in the North Atlantic. DoD.

1999 – present-ongoing: Raven: Design, implementation, and distribution of bioacoustics software instrument. NSF and Cornell.

2007 – present-ongoing: Application of near-real-time auto-detection system for large whale acoustic monitoring and mitigation of Northeast Gateway Deepwater Port. Excelerate Energy and Suez Energy North America.

2010 – 2015: Portable and persistent autonomous real-time marine mammal acoustic monitoring. NOPP-NSF.

2011 – 2016: DCL System Research Using Advanced Approaches for Land-based or Ship-based Real-Time Recognition and Localization of Marine Mammals. NOPP-ONR.

2011 – 2016: CHAOZ-X - An Ocean Observing System for Monitoring and Mapping Marine Mammals and Noise in the Chukchi Sea Ecosystem. BOEM -NOAA-WHOI.

2013 – 2016: Acoustic ecology of predator-prey interactions: encoding and decoding alarm calls in multispecies communication networks. Collaborative research with Erick Greene, NSF.

PUBLICATIONS

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Submitted Papers

Cholewiak, D., Cerchio, S., Jacobsen, J, Urban-Ramirez, J., and Clark, C.W. Acoustic and spatial interactions between singing humpback whales (*Megaptera novaeangliae*) suggest mechanisms that may mediate male competition. Anim. Behav.
Clark, C.W., and Gagnon, G.C. 2015. Fin Whale Swimming Speed and Song Variability. Journal of Underwater Acoustics, USN declassified, so I can now submit to unclassified journal.

GRADUATE FIELD MEMBERSHIPS

Neurobiology and Behavior
Zoology

GRADUATE MAJORS (serve as chair)

Total Completed

John Bower (NB&B, Ph.D.2000)
Bernard Brennan (NB&B, Ph.D., 2005)
Renata de Sousa Lima Mobley (Zool. - DNR, Ph.D., 2007)
Danielle Cholewiak (NB&B, Ph.D., 2008)
Mya Thompson (NB&B, Ph.D., 2008)

GRADUATE Ph.D. MINORS (member of graduate committee)

- **Total Completed**

Peter Marchetto (2015)

Ingrid Biedron (2014)
Dan Pendleton (2009)
Lynn Fletcher (2008)
Yianna Samuel (2007)
Damian Elias (2007)
Andrew Farnsworth (2006)
Leila Hatch (2005)
Karen Fisher (2002)
Hamilton Farris (2000)
Matt Weeg (2001)
Paul Faure (1999)
David Haskell (1998)
Jessica McKibben (1998)
Andrea Lee (1997)
Beth Weisburn (1996)
Stacey Benton (1999)
David Haskell (1996)
Adam Frankel (1994)