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MARINE ENVIRONMENT PROTECTION COMMITTEE
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Agenda item 18

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ANY OTHER BUSINESS

Scientific support for underwater noise effects on marine species and the importance of mitigation

Submitted by Canada

SUMMARY

Executive summary:	This document highlights the scientific support for shipping's contribution to the ocean soundscape and the impact of noise on marine species. Commercial shipping is the largest global contributor of underwater noise to the ocean soundscape, which reinforces the need to ensure that related activities are balanced with the need for oceans to remain healthy and diverse in the long term.
Strategic direction, if applicable:	4
Output:	Not applicable
Action to be taken:	Paragraph 24
Related documents:	MEPC 72/16/5 and MEPC 58/19

INTRODUCTION

1 Sound in the world's oceans originates from many sources, such as storms, animals, earthquakes, commercial shipping, marine construction, military activities, oil and gas exploration and production, and even clouds of bubbles. Sound travels through water far better than does light, which is why many marine organisms rely on their hearing to find prey, to avoid predators and to communicate.

2 Measurements taken over the last 50 years indicate an increase in some areas in anthropogenic noise emissions into the marine environment. The main sources include vessel traffic, seismic exploration, industrial activities and construction (e.g. pile driving, drilling, tunnel boring and dredging), military and commercial sonar, acoustic deterrent devices, oceanographic experiments and explosions for underwater construction (Hildebrand, 2009; Green Marine Corporation, 2016). While high intensity and impulsive noise sources, such as seismic testing and pile driving, are thought to pose the greatest risk of acute injury

(Southall et al., 2007), lower levels of continuous, chronic noise have created serious health impacts for marine mammals. The largest contributor of anthropogenic noise to the marine environment is conclusively commercial shipping, particularly in the low frequency range (Ross, 1993, 2005; Andrew et al., 2002; McDonald et al., 2006, 2008; Hildebrand, 2009; Chapman & Price, 2011; Frisk, 2012).

3 Underwater noise from commercial shipping has the potential to adversely impact a variety of aquatic animals including whales, fish, turtles and invertebrates that use sound to communicate, navigate and forage (see, e.g., Erbe & Farmer, 1998; Erbe, 2002; André & Degollada, 2003; Buckstaff, 2004; Smith et al., 2004; Weilgart, 2007; Clark et al., 2009; André et al., 2011; Nedelec et al., 2015; Williams et al., 2015; Filiciotto et al., 2016; DFO, 2017; Weilgart, 2018). Fortunately, there are strategies and measures that can be used to mitigate underwater noise levels. By changing ship speed, vessel load, operational mode or improving hull or propeller designs, vessel noise emissions can be mitigated (see e.g., OSPAR Commission, 2009; Leaper & Renilson, 2012; Spence & Fischer, 2017) and wear on the equipment can be reduced.

4 The purpose of this document is to highlight some of the existing evidence explaining the contribution of commercial shipping to ocean noise and its impact on marine species. The research cited hereinafter is not exhaustive but represents a sample of current knowledge across a range of species and ecosystems. References are cited throughout and full biography is included in the annex.

SHIPPING'S CONTRIBUTION TO UNDERWATER NOISE

Source of noise

5 The largest contributor of low frequency anthropogenic noise to the marine environment is conclusively commercial shipping (Ross, 1993, 2005; Andrew *et al*., 2002; McDonald *et al*., 2006, 2008; Hildebrand, 2009; Chapman & Price, 2011; Frisk, 2012). This noise derives mainly from propeller action, equipment used in the propulsion of the ship (e.g., shafts, gears, engines and other machinery), and the flow of water over the hull (Hildebrand, 2005; 2009). Propeller action creates noise by cavitation, referring to the low pressure area around the blades that produce tiny bubbles. The bursting of these bubbles results in about 80-85% of the noise produced by ships (Ross, 1987; Hildebrand 2005; Southall, 2005; IMO, 2010). An increase in the size of a ship can also result in more low frequency noise radiated into the environment. The noise contribution from commercial shipping is unintentional, unlike the noise generated by other sources, and results in a less efficient vessel due to the energy loss associated with cavitation. In other words, there is no useful purpose related to the generation of noise from commercial shipping which strongly suggests that measures to reduce the underwater noise from commercial shipping will provide a benefit not only to the soundscape of the oceans but also to the overall energy efficiency of commercial vessels to which these measures are applied.

Overlap of ship noise with marine species

6 Sound can be measured on a scale of loudness in decibels (dB) and frequency in Hertz (Hz), which refers to the pitch of the sound. For example, a bass drum can create a low frequency sound (e.g., 20 Hz) while a dog whistle creates a high frequency sound (e.g., 23 000 Hz).

7 Both the loudness and the frequency at which sounds are produced will determine the level of impact on marine species. Figure 1 shows how the frequency of shipping related noise overlaps with the hearing frequency of many marine species.

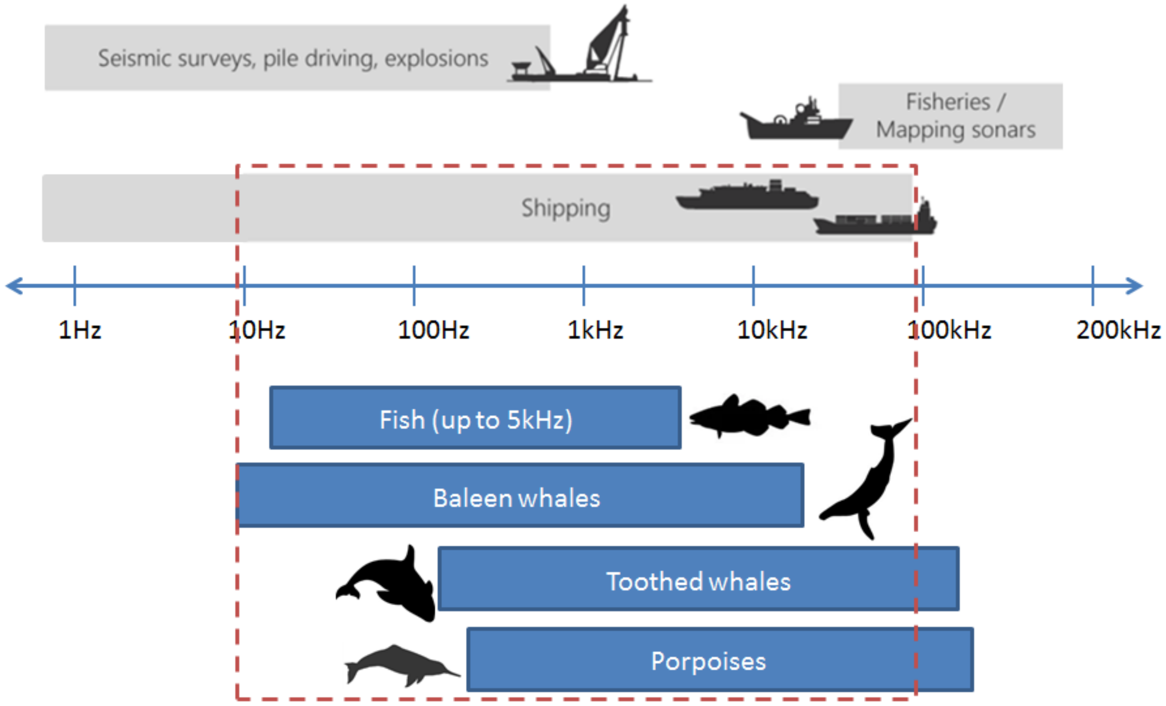

Figure 1 – Overlap in the predominant frequencies of marine animal hearing and anthropogenic sources of underwater noise (modified from Nikolopoulos et al., 2016; Veirs et al., 2015; and NMFS, 2016). Although the bars representing the range in frequencies encompass the majority of source examples or species, some aquatic activities or marine mammals exceed these frequencies. Other references may cite slightly different ranges than those referred to in this figure, but this may be the result of the difference in categories chosen for representation or the difference in underwater features where the measurements were drawn. The red dashed box outlines the frequencies radiated by shipping that overlaps with the frequencies of animal hearing.

THE IMPACT OF UNDERWATER NOISE ON MARINE SPECIES

Impacts on invertebrates

8 Scientific studies conducted in laboratory environments under controlled conditions have recorded disturbance responses from species of invertebrates as a result of vessel related noise. In one study, foraging, behaviour, and oxygen consumption of the shore crab (*Carcinus maenas*) was shown to be affected upon the exposure to ship noise recordings (Wale *et al*., 2013). The crabs became more distracted from food, took longer to find asylum from predator stimuli, and exhibited increased oxygen consumption, potentially demonstrating elevated levels of stress. Additionally, no amount of repetition of the experiment brought about habituation to the stimuli. In other words, the crabs never got used to the ship noise recordings. These results show that some invertebrates are affected by vessel noise, potentially leading to an increased risk of starvation and predation.

9 Other studies showed that noise can also create physical damage to the animal. High intensity noise exposure experiments (simulating seismic activities) on squid and octopuses resulted in hair cell (used for hearing) damage and lesions (Andre et al., 2011; Solé et al., 2013). Related research conducted on scallop embryos resulted in malformations (Aguilar de Soto *et al*., 2013). Experiments that used recordings of vessel noise showed that embryos of sea hares (a type of mollusc) exhibited increased rates of mortality (Nedelec et al., 2014). Additionally, exposure to vessel noise produced significant changes in protein

concentrations, DNA integrity, and protein expression in the brain tissues of the common prawn (Filiciotto et al., 2016). Blue mussels exposed to similar noise levels produced stress-related chemicals at concentrations capable of degrading their own DNA (Wale et al., 2016).

10 Some research also suggests that vessel noise could increase survival rates of unwanted aquatic invasive species, such as the sea squirt, a known fouling organism. In the presence of ship noise, sea squirt larvae actually showed significant increases in their rates of settlement and metamorphosis, and therefore survival (McDonald et al., 2014). In fact, the loudest area of the vessel was found to have the greatest amount of fouling.

Impacts on fish

11 Scientific research to determine the impacts of underwater noise on fish have been conducted either in a controlled laboratory setting or in underwater cages to measure a more natural response. Research on the European eel (*Anguilla anguilla*), for example, provides evidence of elevated stress levels and impaired attention when recordings of shipping noise are heard (Simpson et al., 2014). This can result in an inability to sense and acknowledge the presence of a predator. Additionally, scientific observations of a number of fish species (e.g., perch, roach, damselfish, convict cichlids, mulloway fish) indicate that motorboat noise results in an escape response and a hesitancy to forage when hungry. The reduction in time spent feeding can result in an adaptation of normal feeding patterns (i.e., daytime foragers became sunset foragers as a result of a reduction in traffic at dusk), a 61% decrease in stomach contents, and diminished health (Bracciali et al., 2012; Payne et al., 2014; McLaughlin & Kunc 2015; Magnhagen et al., 2017). Noise has been shown to impact fish in other ways as well. For example, underwater sound (various frequencies were tested) has been shown to impair the hearing of some fish (Smith et al., 2004; 2011). Fortunately, some of these species have the ability to regrow the damaged cells (i.e., hair cells in the inner ear) thus rendering the limiting condition temporary (Popper & Hastings, 2009). However, it may take several days to weeks to complete the healing process, and these individuals are left vulnerable in the meantime.

12 Other studies have shown that exposure to sounds sustained for longer periods of time can result in a range of serious impacts (see Figure 2). Additionally, many fish species use sound during their critical life stages, which can be easily affected by noise (Staaterman & Paris, 2013). For example, one study showed that noise exposure applied habitually to a broodstock population of Atlantic cod during the spawning window resulted in a significant reduction in total egg production and fertilization rates leading to a 50% loss in the number of viable embryos produced (Sierra-Flores et al., 2015). Moreover, when the larval stage of Atlantic cod was exposed to sustained levels of ship noise, poorer body condition and a reduced ability to escape predators resulted (Nedelec et al., 2015). Thus shipping noise can decrease the production of embryos and the likelihood of spawn surviving to adulthood and thus their contribution to the expansion of the population.

13 The impact of underwater ship noise on individual fish species, as described above, can lead to lasting impacts at the population level including reduction in population size, reduction in total biomass and changes in spatial distribution (see Figure 2). This is especially important for fish stocks of economic significance that are already below sustainable levels, such as Atlantic cod, haddock, snapper, grouper, and red drum (NMFS, 2016). Vessel noise has also been shown to reduce fishing catch rates in some cases (Weilgart, 2018).

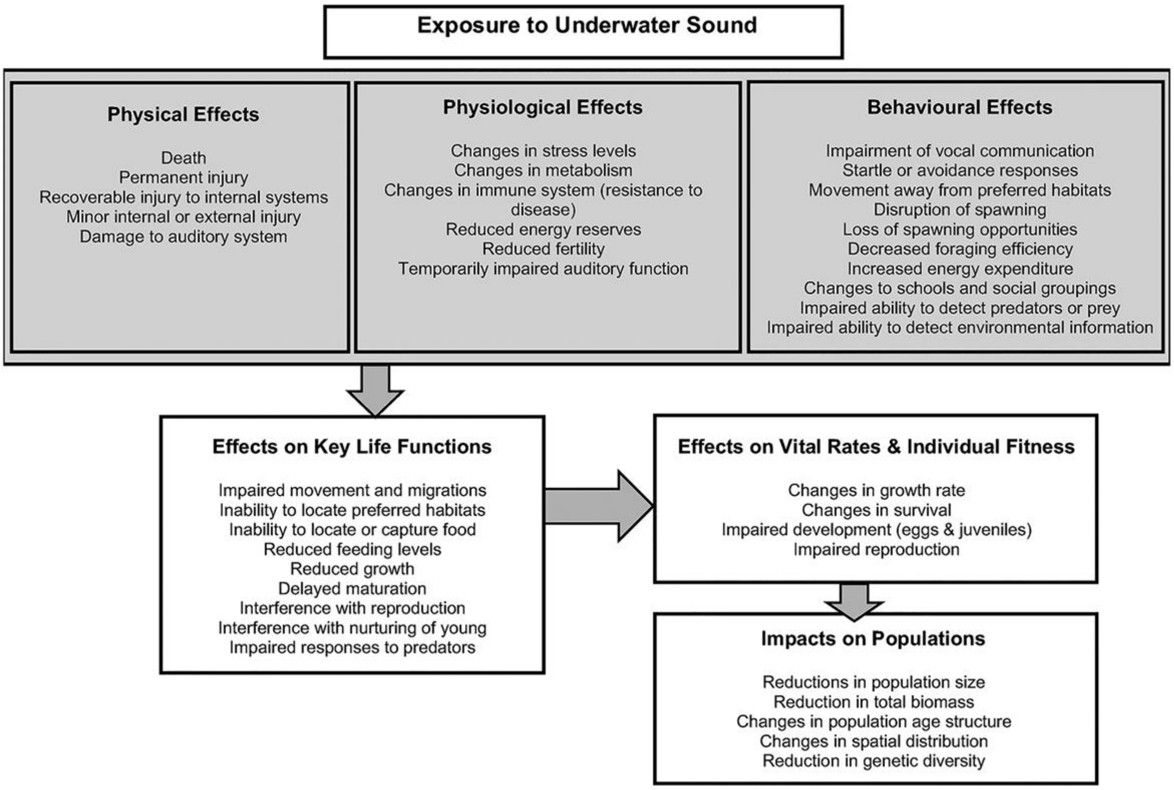

Figure 2 – Summarizing flow chart of the effects of underwater noise on fish (and possibly invertebrates) (obtained from Hawkins & Popper, 2016). This information provides a special focus on important biological functions and how these impacts produce an effect observed at the population level.

Impacts on marine mammals

14 Numerous field studies have found that marine mammals, including whales, respond to shipping related noise in a variety of ways. Anthropogenic noise can result in a disruption of communication, decrease in foraging, increased stress, temporary or permanent hearing impairment, and in extreme cases death (DFO 2011). Furthermore, some individuals may be ill equipped to deal with shipping related noise. For example, the physical and biological demands of migration or nursing a juvenile marine mammal may leave an adult in such poor condition that they are unable to escape or have the capacity to respond to the added environmental stress from underwater noise (Tyack, 2008). This additional stress may also put juveniles at risk or inhibit females from producing young in the first place (see e.g., New *et al*., 2013). A recovering population of marine mammals requires a certain amount of growth each year through reproductive success to avoid decline. The effects to individuals, as described above, can have an impact at the population level. For example, disruption from ships has been found to reduce socializing and feeding in dolphins in Istanbul Strait (Bas, et al, 2017). This is especially concerning for marine mammal populations that are already imperiled, such as the Southern Resident killer whale population (see e.g., Williams et al., 2006; Noren, 2011) and the North Atlantic right whale population (DFO, 2014).

Masking communication

15 Masking is the "drowning out" of sounds of interest to marine species. Low frequency emissions from commercial shipping have been shown to mask communication signals between seals, sea lions, and baleen whales (Payne & Webb, 1971; Hildebrand, 2005), including the endangered North Atlantic right whale (Clark et al., 2009; Hatch et al., 2012).

In contrast, the high frequency emissions produced by cavitation noise from ship propellers have been shown to mask communication between toothed whales such as belugas (Erbe & Farmer, 1998; Simard et al, 2016), bottlenose dolphins (Buckstaff, 2004; Morisaka et al., 2005; Jensen et al., 2009), short-finned pilot whales (Jensen et al., 2009), Cuvier's beaked whale (Aguilar de Soto et al., 2006), and killer whales (Erbe, 2002; Holt et al., 2009; 2011). One study provided evidence indicating that noise emitted from small vessels in the coastal zone reduced the communication range of pilot whales in nearby habitat by 58% (Jensen et al., 2009).

Reduced foraging efficiency

16 Shipping related noise may also reduce the hunting efficiency of some predatory marine mammals. For example, a reduction in foraging behaviour as a result of vessel noise disturbance (from container ships, commercial freight ships, ferries, tankers, commercial whale-watching vessels, recreational and research vessels, cruise ships, and sport and professional fishing vessels) has been observed in dolphins (Allen & Read 2000), Blainville's beaked whales (Pirotta *et al*., 2012), harbor porpoises (Wisniewska *et al*., 2018) and killer whales (Lusseau *et al*., 2009).

17 For the Southern and Northern Resident killer whales in particular, short term disturbance from commercial fishing boat traffic has been shown to disrupt their foraging behavior (Williams et al., 2006), while chronic noise from shipping and small boat traffic masks the social calls that they use to coordinate group hunting movements (Williams et al., 2013) and their ability to echolocate – the process of bouncing sound off objects such as prey to locate them (Holt, 2008). One study on Southern Resident killer whales found that this population spends approximately 25% less time feeding in the presence of boats (including commercial whale-watching vessels, recreational and research vessels, cruise ships, sport and professional fishing vessels, and commercial freight ships) than in their absence (Lusseau et al., 2009). Another study on Northern Resident killer whales quantified the decrease in energy intake to be approximately 18% as a result of the cessation of feeding behavior in the presence of vessels (Williams et al., 2006).

18 A decrease in prey capture can result in a decrease in overall individual fitness and body condition (NRC, 2005; New et al., 2013). This may be more likely if individuals increase swimming effort in attempts to capture prey, albeit unsuccessfully, in the distracting and disorienting presence of vessel noise. The increase in energy expenditure from hunting prey combined with the lack of nourishment may leave the individual unable to properly manage other stressors typically found in the environment (e.g., predator/danger evasion, growth demands of the juvenile life stage) (Wisniewska et al., 2018).

Increase in stress levels

19 Additional evidence in support of the negative impacts of vessel noise comes from a highly cited study in Bay of Fundy, Canada, on the stress levels measured in the endangered North Atlantic right whale. As a result of the events of September 11, 2001, decreased ship traffic in the area resulted in a 6 dB decrease in underwater noise. This 6 dB decrease resulted in an important reduction of stress-related faecal hormone metabolites in individuals of this species (Rolland et al., 2012).

Hearing damage

20 There is potential for hearing damage or loss in whales that are exposed to prolonged periods of shipping noise (OSPAR Commission, 2009). Necropsies conducted on two whales killed in vessel collisions showed evidence of inner ear damage and auditory nerve degeneration from low frequency noise emissions radiated from ships (André & Degollada,

2003). Animals that experience hearing damage may have an impeded ability to forage, communicate, or orient themselves, potentially resulting in strandings (Hildebrand, 2005).

CONCLUSION

21 Multiple scientific studies since 2000 have concluded that ships are the greatest contributors to overall rising levels of ocean noise, especially, but not exclusively, in coastal areas where their numbers are more numerous (Ross, 1993, 2005; Andrew et al., 2002; Kipple & Gabriele, 2003; McDonald et al., 2006, 2008; Hildebrand, 2009; Chapman & Price, 2011; Frisk, 2012). Furthermore, commercial shipping activity is projected to increase globally, more so in some geographic areas than others (Frisk, 2012). While there is still considerable uncertainty about the full impacts of underwater noise on marine species, noise from shipping is shown to have important impacts on many species, specifically with regards to their ability to communicate and forage.

22 As a global issue, participants at the 2008 Hamburg International workshop on Shipping Noise and Marine Mammals agreed upon a specific noise reduction target to reduce the contributions of shipping to ambient noise levels. The targets are to reduce vessel-related noise globally by 3 dB (i.e., in the 10-300 Hz range) in the span of 10 years and by 10 dB in 30 years, relative to current levels. These targets have been endorsed by the Scientific Committee of the International Whaling Commission. However, the concept of "target levels" for noise remains an outstanding question requiring research, as the "ideal" target levels will likely vary with location, species, and season.

23 Marine environments provide the world with a number of invaluable resources that support economic growth. The species themselves provide a source of food, financial means for those that harvest them, medicines and scientific breakthroughs to those that study them and opportunities for recreational activities. The interconnectedness of species within an ecosystem can have cascading effects if a single species is affected, no matter how small. By maintaining biodiversity (i.e., an array of different species in an ecosystem) in our aquatic environments, species populations are more stable and resilient in the face of adverse events. However, the latest estimates determine that at least 130 marine species are affected by underwater noise (Weilgart, 2018). Therefore, it is imperative that we consider the mitigation of noise in our global aim to protect and maintain the species in these habitats for generations to come.

ACTION REQUESTED OF THE COMMITEE

24 The Committee is invited to take note of this information.

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ANNEX

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