Reducing Underwater Noise through Underwater Noise Management Plans

Comments by the Wildlife Conservation Society Canada

March 14, 2019

These comments are in response to Transport Canada's January 2019 Technical Discussion Paper *Reducing Underwater Vessel Noise through Underwater Noise Management Plans*. They address questions posed in that paper, preceded by general comments about the overall approach as well as factors to be considered when adapting a national approach to Arctic circumstances.

Summary of key recommendations

1. **Underwater Noise Management Plans need to be specifically developed for Arctic circumstances**. There's an opportunity for proactive planning in the Arctic, where anthropogenic noise levels are low compared with other oceans but where increasing ship traffic will therefore have a relatively high impact. Anthropogenic noise thresholds should therefore be lower in the Arctic. However, this also means that Arctic-specific UNMPs can be developed with the aim of preventing anthropogenic noise from becoming a serious issue in the first place, rather than simply mitigating an existing problem.

2. **Fleet-level approaches do not supplant the need for other measures.** Regional restrictions are aimed at minimizing impact in particularly sensitive areas, and maximum noise limits on individual vessels address the specific impacts caused by particularly noisy ships. These measures are important, and fleet-level measures that lower overall fleet volume profiles don't address these issues.

3. **Underwater Noise Management Plans should allow for regular review and improvement.** Our understanding of noise and its impacts is continuing to evolve, and therefore any UNMP program – and the UNMPs themselves – will need to be subject to regular review and continual refinement. The shipping industry, the scientific community and regulators should wherever possible be working together in a collaborative manner to ensure that research addresses priority needs, and that research findings are incorporated into the UNMPs on an ongoing basis.

About Wildlife Conservation Society Canada

WCS Canada's (www.wcscanada.org) mission is to save wildlife and wild places in Canada through science, conservation action, and inspiring people to value nature. Our trademark is "muddy boots" biology, which we do by getting in the field and conducting the necessary research to fill key information gaps on Canada's fish, wildlife, and ecosystems. We then use relevant information and our expertise, working with Government and regulatory agencies, conservation groups, indigenous communities and industry, to resolve key conservation issues.

WCS Canada is a national affiliate of the Wildlife Conservation Society, which has been working in the Arctic since 2002, with the Arctic Beringia program formally established in 2011. Our work in the Canadian Arctic has focused to a large extent on what can be learned from passive monitoring of the acoustic environment of Arctic waters; gathering information on the activities of marine mammals, fish and ships, and the impact of ship traffic on the behaviour of the wildlife, and using that knowledge to model impacts and the efficacy of mitigation measures.

Limitations of a fleet-level approach

As described in the Technical Discussion Paper, Underwater Noise Management Plans (UNMPs) are intended to be developed at the fleet level, and not for individual vessels. Three approaches are proposed: 1) defining fleet-level mitigation measures; 2) setting fleet-level noise reduction targets; or 3) creating a points-based system. In our responses below to the questions posed by the discussion paper, we consider and respond to these options, but at the outset we'd like to highlight a significant short-coming of fleet-based approaches to mitigating underwater noise. Fleet-level plans can, if they are effective, reduce the overall average noise levels, while giving flexibility to fleet operators to determine how best to achieve these reductions. However, without there also being maximum noise limits set there remains a risk that individual ships might continue to emit noise at dangerous levels. When it comes to localized impacts, peak noise from individual vessels can be particularly harmful, even when overall average noise levels across an entire fleet are reduced. Therefore, it will be important to accompany any fleet-level UNMPs with defined maximum peak noise volumes for individual vessels. In other words, whichever target or points-based system is ultimately adopted, it'll be important to supplement that guidance with specific mitigation measures aimed at keeping peak noise volumes below defined thresholds.

Arctic circumstances

Circumstances in the Arctic Ocean differ notably from those in Canada's other oceans, and this distinction should be reflected in the way UNMP guidance is developed and implemented. Overall ship traffic is significantly lower than in other oceans, and the peak traffic areas are considerably less heavily used than high-traffic areas in other coastal regions. This might suggest that the challenge of managing underwater noise is of a lesser level of concern. This would be a mistake however, since underwater noise from shipping in the Arctic is projected to rise in the coming decades. In absolute terms, the Arctic is likely to remain quieter than many regions around the world where anthropogenic activity is particularly intense. But the *relative* change may be dramatic. When ambient levels are low the introduction of anthropogenic noise will have a greater impact than in a region where the ambient levels are already high. What's significant about this is that, for Arctic wildlife including marine

mammals, fishes and invertebrates, the relative increase in sound levels and/or new noise sources may result in behavioural impacts, even if the absolute volume remains lower than in noisier oceans.

Put most simply, Arctic wildlife are not acclimated to noisy environments and therefore may be disproportionately affected by even modest noise increases. Therefore, UNMPs should factor in both broad regional considerations (e.g. reflecting arctic circumstances) as well as specific targets geared to regions known to have particular concentrations of marine mammals.

There are other characteristics of the Arctic acoustic environment that are distinctive to or more prevalent in polar regions. There are noise sources that are particular to those areas, including natural noises caused by ice formation and break-up as well as anthropogenic noises emitted by ice breakers ramming into ice. Furthermore, sound propagates differently in Arctic waters. Sound can become trapped in the Arctic sound channel near the surface of the water and propagate over much greater distances at shallower depths than in non-Arctic waters. Perhaps most importantly, the culture and livelihoods of Indigenous peoples in the Arctic depend on the continued health of marine mammals to a greater degree than in other regions of the world. Noise impacts affecting the behaviour of these mammals and thus the ability of hunters to be successful will be immediately felt in these communities and therefore deserve proactive attention.

Moreover, experience gained in Atlantic and Pacific waters demonstrates that by the time noise levels reach the point where mitigation measures are being considered the impacts are already unacceptably high, and the "ratchet effect" makes it relatively difficult to move towards reduced noise levels. In the Arctic there's an opportunity to implement proactive measures, but this will require an overall approach that puts a stronger emphasis on precautionary measures than would necessarily be feasible in other waters.

Our further comments below respond to the questions posed in the 'Seeking Your Views' sections of the discussion paper.

Section 3 Underwater Noise Management Plans

What should be the trigger for requesting or requiring development of a UNMP?
Any new routes or operational conditions should trigger a UNMP, especially if the route transits rich or biologically important areas.

3.2 Targeted Underwater Noise Reductions

Should fleet owners be responsible for setting individual targets in their plan?
The discussion paper outlines options in which targets are based on regional baselines, or all fleets reduce noise by a set amount. In neither of these cases would the fleet owner be responsible for setting a target. It's not reasonable to expect fleet owners to understand the issue in sufficient detail to set their own targets.

A regional baseline may be logistically and technically easier to achieve than a fleet-based baseline. What advantages or disadvantages do you see for a system in which each organization's contribution to achieving a regional goal differs?

A regional baseline is a necessary first step. However, in order to distribute responsibility for meeting a noise reduction target across multiple operators within a region it'll be important to also develop fleet-based baselines. These data can be used to estimate the contribution of the fleet to the regional background noise level and will be important in determining priorities for reducing overall noise levels.

Should noise reduction targets be a number of decibels (broadband) or within a specific frequency range?

Noise reduction targets should be set for broadband noise levels (reducing general impact) as well as for specific frequencies, aimed at mitigating impacts on particular species of concern in a particular region. In addition to absolute noise levels, of particular concern regarding noise impact on animals is narrow-band acoustic energy (e.g. tonal peaks). This noise feature should be identified and prioritized for mitigation for each vessel type. These noise types are often much more audible at low levels and often cause strong reactions among animals, even at low levels. This is an important aspect of underwater noise impact that is not currently well understood. The important point to note is that noise disturbance is not always simply related to absolute noise level.

The science is definitely evolving which must be made clear to industry (in this case shipping) so that they do not interpret updates as "moving the goalposts". An ideal scenario is for industry to be directly involved in the science through collaborations so that the details that are evolving are more clearly appreciated. The primary aspect of the science that is evolving is the understanding of animal impacts. As this evolves (as noted above), we often find that the absolute acoustic level (i.e. in decibels or dB) is not as important as other aspects of the noise (e.g. tonality, amplitude fluctuations, signal onset time, or biological salience). Of particular difficulty is understanding the relationship of signal salience (i.e. meaning; for example, does it sound like a predator) to impacts. The more frequently the criteria are updated, with industry as closely linked as possible, the better.

What advantages and disadvantages do you see in using a points-based system, which does not rely on hitting a set noise reduction target or measuring baselines in order to achieve noise reductions?

A points-based system would certainly be easier to implement, but it's unlikely to be effective. Fleet operators will gravitate towards implementing the measures that achieve the required points with the least effort, but unless the point system is flawlessly calibrated (which is virtually impossible to do) those measures won't result in proportionate noise reductions. Moreover, it will be very difficult to monitor the efficacy of such a system.

3.3 Target Groups

How should vessels be targeted for the development of UNMPs (e.g. by location, noise level, vessel size, class, fleet size)? Should UNMP requirements be the same for all groups?

Vessels should be targeted based on their contribution to overall noise levels, with supplementary criteria that would apply in areas where there are known concentrations of marine mammals. UNMP requirements should be adapted for specific vessel types, so that there are incentives to reduce noise

levels for all vessel types, more stringent reduction requirements for noisier vessels and absolute limits on peak volumes.

3.5.2 Baseline information

Baseline information should include acoustic source levels for each vessel and normal operating conditions (e.g. speed). This would be the responsibility of fleet owners, using commonly established criteria (size, engine/propeller type, etc.), and is needed in order to calculate a fleet baseline. This should be supplemented by background noise baselines for particular regions, which is used to set overall noise reduction targets.

3.6 UNMP review

Should UNMPs be made publicly available online, filed with Transport Canada, or kept by the business owner/operator?

As noted in the discussion paper, UNMPs will need to be reviewed by Transport Canada (which may use an accredited third party to carry this out on behalf of Transport Canada). It will, however, be important for these plans to be made available online, with whatever detail is appropriate. This transparency will allow for expert review to ensure that the measures are evidence-based and reflect evolving information about the issue. It will enhance the public relations benefit of these plans to fleet owners, and will hopefully encourage continual improvement within plans, as fleet owners review the UNMPs of other fleets and respond by making incremental improvements to their own plans.

4. Potential Underwater Noise Mitigation Measures

What resource materials are you aware of that could be useful as guidance in support of development of UNMPs?

Attached to this submission is a matrix of recommendations and guidelines on anthropogenic underwater noise, compiled by Emily Chou, Brandon Southall and Howard Rosenbaum for WCS, with information drawn from Inter-Governmental Organizations and associated conventions, from Governmental organizations and from selected best-practise publications for mitigating underwater noise.

Additional source material, which is of particular relevance to Arctic conditions:

- Halliday WD, Insley SJ, Hilliard RC, de Jong T, Pine MK (2017) Potential impacts of shipping noise on marine mammals in the western Canadian Arctic. Marine Pollution Bulletin 123: 73-82. DOI: 10.1016/k.marpolbul.2017.09.027
- Pine MK, Hannay DE, Insley SJ, Halliday WD, Juanes J (2018) Assessing vessel slowdown for reducing auditory masking for marine mammals and fish of the western Canadian Arctic. Marine Pollution Bulletin 135: 290-302. DOI: 10.1016/j.marpolbul.2018.07.031
- Halliday WD, Pine, MK, Insley SJ. (2019 In Press) Underwater Noise in the Arctic: A State of Knowledge Report. Arctic Council PAME working group.

5. Success Factors of Effective Management Systems

Are there other key factors of success related to the successful development and implementation of UNMPs?

Our understanding of noise and its impacts is continuing to evolve, and therefore any UNMP program – and the UNMPs themselves – will need to be subject to regular review and continual refinement. The shipping industry, the scientific community and regulators should wherever possible be working together in a collaborative manner to ensure that research addresses priority needs, and that research findings are incorporated into the UNMPs on an ongoing basis.

We welcome the opportunity to comment on this discussion paper and look forward to continued collaboration on this important issue.

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Synthesis of IGO, Governmental, and Selected Publications on General Awareness of Ocean Noise and Management & Monitoring Recommendations

Statements of General Awareness (with references for IGOs, conventions, government policy statements, selected publications)		**Management and monitoring recommendations** (with references for IGOs, conventions, government policy statements, selected publications)	
Marine mammals depend on sound for important biological functions. These functions may be directly or indirectly affected by anthropogenic ocean noise	IWC/67/GEN/05/rev1; UNEP/CBD/MCB/EM/2014/1/2; UNEP/CMS/ Resolution 10.24	Ocean noise should be explicitly managed and monitored in order to better understand ocean soundscapes and reduce potential negative impacts of anthropogenic ocean activities	IWC Contribution to UN ICP Oceans and the Law of the Sea; SC/66b/REP/10; UNEP/CBD/MCB/EM/2014/1/2
	NOAA ONS; Hatch et al. (2016); EU MSFD		NOAA ONS; Hatch et al., 2016; EU MSFD
	Nowacek and Southall (2016)		Nowacek et al. (2015)
Anthropogenic underwater noise has increased in recent decades in many areas due to various industrial activities	IWC/67/05; UNEP/CMS/Resolution 9.19	Ocean noise management and monitoring should consider biologically relevant spatial and temporal scales in order to identify important places and periods, support marine spatial planning and evaluate potential cumulative impacts	IWC Contribution to UN ICP Oceans and the Law of the Sea; SC/66b/REP/10; UNEP/CBD/COP/DEC/XII/23; UNEP/CMS/ Resolution 10.24; MOP8/Doc.6.2.7.b Rev. 1 Section C.1 – C.2
	NOAA ONS; EU MSFD		NOAA ONS; Harrison et al., 2016; Hatch et al., 2016; Nowacek et al. (2015); Nowacek and Southall (2016)
Anthropogenic ocean noise is inherently transboundary in nature and is thus a global issue that will benefit from broad partnerships	IWC/67/GEN/05/rev1; IWC 2017b; UNEP/CMS/Resolution 9.19; UNEP/CMS/ Resolution 10.24;	Management and monitoring may be necessarily focused on key species and habitats in some cases, but should also have broader ecosystem perspectives	SC/66b/REP/10; UNEP/CMS/Resolution 9.19; UNEP/CMS/ Resolution 10.24 Section C.1-C.2
	NOAA ONS; Hatch et al., 2016 EU MSFD		NOAA ONS; Hatch et al. (2016)
	Nowacek et al. (2015)		Nowacek and Southall (2016)
Chronic sources of noise, notably commercial shipping, have the greatest overall contributions to anthropogenic ocean noise	MEPC.1/Circ.833; UNEP/CBD/MCB/EM/2014/1/2; UNEP/CMS/Resolution 9.19	Anthropogenic noise generating activities should be characterized in spatial, temporal, spectral parameters using systematic methods (*e.g.*, Automatic Identification System (AIS) tracking) and measurement standards; data should be made transparently available	SC/65b/Rep03 SC/66b/REP/10; IWC Contribution to UN ICP Oceans and the Law of the Sea UNEP/CBD/COP/ DEC/XII/23; UNEP/CMS/ Resolution 10.24
	Harrison et al., 2016; Hatch et al., 2016		EU MSFD; NOAA ONS; Hatch et al., 2016
			Nowacek et al. (2015)
		Technological measures should be taken to reduce, measure, and evaluate the contributions of anthropogenic ocean noise	MEPC.1/Circ.833; UNEP/CBD/MCB/ EM/2014/1/2; UNEP/CBD/COP/ DEC/XII/23
			EU MFSD; NOAA ONS; Hatch et al., 2016
			Nowacek et al. (2015); Nowacek and Southall (2016)

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Synthesis of IGO, Governmental, and Selected Publications on Noise Impact Mitigation Measures and Quieting Recommendations

Anthropogenic Ocean Noise Mitigation Recommendations (with references for IGOs, conventions, government policy statements, selected publications)		**Quieting Technology Recommendations** (with references for IGOs, conventions, government policy statements, selected publications)	
Efforts to mitigate and reduce negative impacts of ocean noise should not be delayed until there is full scientific certainty about the types and scope of potential issues	IWC/66b/REP/10; IWC/67/GEN/05/rev1; IWC 2017; UNEP/CBD/MCB/EM/2014/1/2; UNEP/CBD/COP/ DEC/XII/23; UNEP/CMS/Resolution 9.19	Specific technological and operational measures should be implemented to reduce incidental noise output and limit deliberate noise-generating activities to the extent possible	MEPC.1/Circ.833 Section 10.4 & 10.5; UNEP/CBD/MCB/EM/2014/1/2; IWC 2014 Overview; MEPC.1/Circ.833; UNEP/CBD/COP/ DEC/XII/23; UNEP/CMS/ Resolution 10.24
	EU contribution to UN ICP; EU MSFD		NOAA ONS Roadmap; Harrison et al., 2016; Hatch et al., 2016
	Nowacek et al. (2015)		Nowacek et al. (2015); Nowacek and Southall (2016)
Anthropogenic noise should be reduced in order to maintain and/or restore natural ocean soundscapes. Specific objectives and limits have been proposed and international partnerships encouraged	SC/65b/Rep03; SC/66b/REP/10; IWC 2014 Overview; UNEP/CMS/Resolution 10.24; UNEP/CMS/Resolution 9.19; UNEP/CBD/COP/ DEC/XII/23;	Highest priority globally for noise reduction efforts should be on large commercial vessels; initial focus should be on propulsion systems	SC/66b/REP/10; MEPC.1/Circ.833 Section 7.2; 7.3; MEPC/72/16/5; UNEP/CMS/Resolution 9.19;
	EU contribution to UN ICP; Directive 2008/56/EC of the European Parliament and of the Council; EU Decision 2017/858; HELCOM NOAA ONS Roadmap		EU MSFD
	Nowacek et al. (2015)		
Mitigation measures should increasingly utilize new technologies and be adaptive to progress in research and monitoring	SC/65b/Rep03; SC/66b/REP/10; MEPC/73/18/4;	Specific recommendations for reduction of shipping noise and evaluation of efficacy	MEPC.1/Circ.833 Section 10.4 & 10.5; MEPC.1/Circ.833;
	NOAA ONS; Harrison et al. (2016); Hatch et al. (2016)		AQUO, SONIC, SILENV, COMMON SENSE, HORIZON 2020 , BIAS, GREEN MARINE, FIBRESHIP projects (see detailed tables)
	Nowacek et al. (2015); Nowacek and Southall (2016)		
Mitigation and reduction of noise impacts should include both technological (quieting) design measures as well as operational approaches	MEPC.1/Circ.833 Section 10.4 & 10.5; UNEP/CBD/MCB/EM/2014/1/2;	Incentive-based programs for quieting technologies should be considered and applied in parallel with or in addition to any requirements/regulations	UNEP/CBD/MCB/EM/2014/1/2;
	Harrison et al. (2016)		NOAA ONS Roadmap
	Nowacek and Southall (2016)		Nowacek et al. (2015); Nowacek and Southall (2016)

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Recommendations and guidelines on anthropogenic underwater noise: Inter-Governmental Organizations (IGOs) and Associated Conventions

Organization/ Convention	General Awareness	Spatial and temporal mapping/management	Assessment/monitoring recommendations	General recommendations: Mitigation	Specific recommendations: Mitigation	General quieting technology recommendations	Specific quieting technology recommendations
International Whaling Commission	Anthropogenic underwater noise has increased rapidly due to activities such as shipping, seismic exploration, drilling, construction, etc. (IWC/67/05). Cetaceans depend on sound for survival and anthropogenic underwater noise can have both physiological and behavioral consequences (IWC/67/GEN/05/rev1). Noise can travel long distance across and beyond areas of national jurisdiction, but anthropogenic underwater noise is not persistent and can be reduced (IWC/67/GEN/05/rev1). Anthropogenic underwater noise affects the marine acoustic environment in many regions which may adversely affect cetacean	Spatial and temporal management of noise-generating activities is important to encourage identification of sensitive areas where management may need to be stricter (IWC Contribution to UN ICP Oceans and the Law of the Sea). Integrate changes in acoustic habitat into population dynamics models to address management questions and effectiveness of noise-reducing technologies (SC/66b/REP/10). Compile a log including spatial and temporal occurrence of noise sources (SC/66b/REP/10). Recommend use of Automatic Identification System (AIS) to relate shipping	Encourage assessments of marine activities to include noise to help reduce harmful impacts to cetaceans (IWC Contribution to UN ICP Oceans and the Law of the Sea). Data collected during seismic surveys should ideally be mandatory, transparent, and publically available to assess the global extent of industry and academic seismic surveys (IWC Contribution to UN ICP Oceans and the Law of the Sea). Inventory of sound source signatures and ambient noise (SC/66b/REP/10). Need for international standardization of underwater acoustic terminology, measurements of sound	Precautionary approach: absence of scientific certainty should not hinder cost-effective, noise-reducing measures or management (IWC/66b/REP/10; IWC/67/GEN/05/rev1; IWC 2017). Consider development of noise exposure limits (IWC Contribution to UN ICP Oceans and the Law of the Sea). Expand efforts to predict population consequences of acoustic masking (SC/66b/REP/10). Reduce shipping noise from shipping set in 2008 by 3 dB in 10 years, and 10 dB in 30 years in the 10 – 300 Hz band (SC/66b/REP/10). Keep flexibility in management tools to	Keep commitments to United Nations Sustainable Development Goal 14 and Convention on Biological Diversity (Aichi Targets 7 and 11) (IWC Contribution to UN ICP Oceans and the Law of the Sea). Member nations undertake management efforts to keep quiet areas quiet and make noisy areas quieter (SC/66b/REP/10). Need for international standardized communication, measurement, and modeling of ocean noise (SC/65b/Rep03). New sound models should include speed dependence, evaluate sound propagation of	Recommend governments promote and facilitate the adoption of noise-quieting technologies (IWC Contribution to UN ICP Oceans and the Law of the Sea). Evaluate ship source characteristics to identify noisiest ships and their contribution to overall noise in order to prioritize ships for replacement or quieting technology (SC/66b/REP/10).	New and retro-fit ship designs to reduce noise should be advanced when and wherever practicable, within IMO goals (SC/66b/REP/10).

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	populations, their prey, and other marine fish and invertebrates (IWC/67/GEN/05/rev1). Addressing anthropogenic underwater noise is crucial to meet United Nations Sustainable Development Goal 14 (SC/66b/REP/10; IWC/67/05). Continued co-operation with other organizations, support efforts of IUCN Joint Species Survival Commission/World Commission on Protected Areas Task Force on Marine Mammal Protected Areas (IWC 2017b).	density to estimated loss of acoustic habitat from shipping noise (SC/66b/REP/10). Efforts to finalize a process to identify Important Marine Mammal Areas (IMMAs) should include information on anthropogenic noise into site selection and management, and reduce ocean noise in identified IMMAs where possible (SC/66b/REP/10).	from ships and ambient sound, and modeling (SC/65b/Rep03).	modify parameters as new information becomes available (SC/65b/Rep03). Increase research efforts to better quantify masking, acoustic space and reduction in prey intake, noise impacts on other life functions other than foraging (SC/66b/REP/10). Consideration of possible impacts from unmanned aerial systems/drones (SC/66b/REP/10). Better understanding of masking release mechanisms, signal-to-noise ratio required for signal detection, recognition and communication needed (SC/66b/REP/10).	pile driving, incorporate industry seismic exploration activities and production source types, and ice noise (SC/65b/Rep03).		
International Maritime Organization	Significant portion of anthropogenic underwater noise is generated by commercial shipping, which can have acute and chronic impacts on marine life (MEPC.1/Circ.833).		Evaluation should be undertaken to determine the success of measures adopted to reduce underwater noise in order to guide and enhance future measures (MEPC.1/Circ.833).	Routing and operations can provide an immediate benefit in reducing underwater noise, but ship design and maintenance provide better long-term solutions	Speed reductions and alternative routes to avoid sensitive habitats and migratory routes (MEPC.1/Circ.833 Section 10.5).	Successful strategies to reduce noise should consider interactions and contributions from other measures that address other objectives such as	Propeller design to reduce cavitation and ensure as uniform water flow as possible into the propeller (MEPC.1/Circ.833 Section 7.2).

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	The technical and cost-effectiveness of measures considered is dependent on design, operational parameters, and mandatory requirements of a particular ship (MEPC.1/Circ.833).			(MEPC/73/18/4).	For ships with fixed pitch propellers, reducing ship speed is effective in reducing underwater noise, especially when ship speed is lower than cavitation inception speed. Ships with controllable pitch propellers might consider optimum combinations of shaft speed and propeller pitch (MEPC.1/Circ.833 Section 10.4).	reduction in onboard noise and energy efficiency (MEPC.1/Circ.833).	Hull: designed such that the wake field is as homogeneous as possible (MEPC.1/Circ.833 Section 7.3). Onboard machinery: request sound level information from manufacturer. Ensure proper location of equipment in the hull. Diesel-electric propulsion, flexible couplings/resilient mountings, and vibration isolation mounts (MEPC.1/Circ.833 Section 8). Additional technologies: state-of-the-art propellers, installation of wake condition devices, and air injection to propeller (MEPC.1/Circ.833 Section 9). Maintenance: reduce surface roughness (MEPC.1/Circ.833

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							Section 10.1 – 10.3). Retro-fitting new Neo-Panamax ships for fuel-efficiency purposes typically also resulted in 8 dB reduction in the 100 – 1000 Hz frequency band and fuel savings (MEPC/72/16/5).
Convention on Biological Diversity	Anthropogenic underwater noise impacts marine and coastal biodiversity and guidance and toolkits to minimize and mitigate adverse impacts should be considered (UNEP/CBD/MCB/ EM/2014/1/2). Ocean noise is intimately linked to the well-being of many marine species and maintaining healthy marine ecosystem (UNEP/CBD/MCB/ EM/2014/1/2). Sound is crucial in communication, navigation, orientation, feeding and detection of predators, and	Development of acoustic mapping in priority areas, including different types of vessels and measurement of source levels of ships to build more complete map of spatial and temporal distribution of sound (UNEP/CBD/MCB/ EM/2014/1/2; UNEP/CBD/COP/ DEC/XII/23). Acoustic mapping should be combined with habitat mapping of species of concern to identify high-risk areas (UNEP/CBD/MCB/ EM/2014/1/2). Consideration of	Develop standardized metrics and sound measurements (UNEP/CBD/COP/ DEC/XII/23). Concerns about long-term, cumulative effects of underwater noise, which are largely unknown (UNEP/CBD/MCB/ EM/2014/1/2). Conduct impact assessments and monitoring for activities that may have more adverse impacts on sensitive species (UNEP/CBD/COP/ DEC/XII/23).	Though long-term, cumulative effects of anthropogenic underwater noise are largely unknown, policy action should address, minimize and mitigate potential impacts (UNEP/CBD/MCB/ EM/2014/1/2). Engage industry, relevant international and regional organizations, governments, and scientific groups to distribute relevant scientific information and help stakeholders understand scientific information and advice (UNEP/CBD/MCB/ EM/2014/1/2).	Areas that are critical for a short period of time (e.g. spawning sites, seasonal feeding areas) can be protected to avoid interference (UNEP/CBD/MCB/ EM/2014/1/2). Compile mitigation toolkits from different countries and tailor them for countries just starting to address anthropogenic underwater noise with respect to the country's socio-economic status, culture, and scientific and technological capabilities (UNEP/CBD/MCB/	Regulators have an important role in incentivizing the development of quieter technologies (UNEP/CBD/MCB/ EM/2014/1/2).	Development and transference of quieter technologies (UNEP/CBD/COP/ DEC/XII/23).

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	anthropogenic underwater noise can affect these functions, behaviors and cause serious injury or death (UNEP/CBD/MCB/EM/2014/1/2). Build national-level political awareness and policy commitment to address anthropogenic underwater noise through workshops, knowledge exchange, web-based tools, policy briefs, etc. (UNEP/CBD/MCB/EM/2014/1/2). Build capacity in developing regions by involving academic/research institutions and engage NGOs and other civil society organizations to address anthropogenic underwater noise. Strengthen awareness on environmental impact assessments (EIAs), guidelines and mechanisms to address underwater noise issues in these regions (UNEP/CBD/MCB/EM/2014/1/2).	appropriate spatial and temporal scales based on length of time of exposure and biological processes to determine noise effects (UNEP/CBD/MCB/EM/2014/1/2). Critical areas that are occupied for short periods of time can be avoided, as well as sensitive time periods (UNEP/CBD/MCB/EM/2014/1/2). Mitigate and manage anthropogenic underwater noise through spatio-temporal management of activities, spatio-temporal knowledge of species or population distributions and ability to avoid generating noise in those areas during those times (UNEP/CBD/COP/DEC/XII/23). Link information on noise impacts in processes/management plants related to marine spatial planning and		Develop best management practices, recognizing that industries may have their own best practices and that best practices within industries and countries may differ depending on legislation (UNEP/CBD/MCB/EM/2014/1/2). Encourage Parties, governments, indigenous and local communities, and relevant stakeholders to take appropriate measures to avoid, minimize and mitigate potentially significant adverse impacts of anthropogenic underwater noise on marine and coastal biodiversity (UNEP/CBD/COP/DEC/XII/23).	EM/2014/1/2). Define and differentiate between types or intensities of underwater noise (UNEP/CBD/COP/DEC/XII/23). Consideration of thresholds to protect sound-sensitive species (UNEP/CBD/COP/DEC/XII/23).		

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	Encourage collaboration and communication among relevant international bodies (UNEP/CBD/MCB/EM/2014/1/2).	area-based management (e.g. MPAs) (UNEP/CBD/COP/DEC/XII/23).					
Convention on Migratory Species	Anthropogenic ocean noise is a form of pollution that can travel over hundreds of kilometers and across national boundaries, and can degrade habitat and have adverse impacts on marine life (UNEP/CMS/Resolution 9.19). Human activities have contributed to a significant increase in ocean noise (UNEP/CMS/Resolution 9.19). Parties to UNCLOS have an obligation to protect and preserve the marine environment and marine mammals (UNEP/CMS/Resolution 9.19). High-intensity mid-frequency active sonar may contribute to incidents of standing and deaths in some cetacean	Integrate anthropogenic noise into management plans of MPAs (UNEP/CMS/Resolution 10.24). Movement patterns and co-occurring disturbances should be considered in order to minimize exposure to noise and reduce cumulative impacts (MOP8/Doc.6.2.7.b Rev. 1 Section C.1 – C.2). Consider scheduling of noise-generating activities during period of low cetacean presence, and spatio-temporal avoidance of high density areas (UNEP/CMS/Resolution 10.24 Section C.1 – C.3).	EIAs should take full account of the impacts of activities on cetaceans and consider noise-associated risks and potential impacts on marine biota and their migration routes for a more holistic approach (UNEP/CMS/Resolution 9.19; UNEP/CMS/Resolution 10.24). Consider noise source information in EIAs, and evaluate indirect impacts of noise displacement (UNEP/CMS/Resolution 9.19; UNEP/CMS/Resolution 10.24 Section C.1 – C.2). Define noise source levels transmitted to the environment before start of an activity (UNEP/CMS/	Strongly urge Parties to prevent adverse effects on cetaceans and other migratory marine species by reducing the emission of underwater noise, keeping it to the lowest necessary level (UNEP/CMS/Resolution 10.24). Where noise cannot be avoided, urges development of regulatory framework to ensure reduction or mitigation of anthropogenic underwater noise (UNEP/CMS/Resolution 10.24). Apply best available techniques and best environmental practice in efforts to reduce noise pollution (UNEP/CMS/Resolution 10.24).	Adopt mitigation measures for high intensity active naval sonar until transparent assessment of their environmental impact is complete to prevent impacts to important habitats and sensitive species (UNEP/CMS/Resolution 9.19). Facilitate studies on the extent and potential impact of high-intensity active naval sonars and seismic surveys on the marine environment (UNEP/CMS/Resolution 9.19).		Use of noise reduction techniques for offshore activities (e.g. air-filled coffer dams, bubble curtains, hydro-sound dampers, floating platforms, gravity foundations) (UNEP/CMS/Resolution 10.24).

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	species (UNEP/CMS/ Resolution 9.19). IUCN recognizes that lack of scientific certainty should not postpone measures to prevent or reduce potential harmful effects cause by ocean noise (UNEP/CMS/ Resolution 9.19). Concern about potential adverse impacts from anthropogenic ocean noise on cetaceans and other biota, and threat to cetacean conservation and welfare (UNEP/CMS/ Resolution 10.24). Need for ongoing and further internationally coordinated research on impacts of underwater noise on cetaceans and other migratory species, and migratory routes in order to provide adequate protection (UNEP/CMS/ Resolution 10.24).		Resolution 10.24). Development of criteria to be considered in order to assess potential risks of signal-generating activities (e.g. amplitude, signal structure, seasonal variability in risk potential) (UNEP/CMS/ Resolution 10.24). Consider real-time monitoring during activity (UNEP/CMS/ Resolution 10.24). Facilitate collaborative and coordinated monitoring and assessment of local ambient noise, and further understanding of potential impacts of noise (UNEP/CMS/ Resolution 9.19). Characterization of anthropogenic noise sources and sound propagation for assessment of potential acoustic risks at the species level (UNEP/CMS/ Resolution 9.19).	Stresses the need to consult with any stakeholder conducting noise-generating activities on how best practices of avoidance, reduction or mitigation of risk should be implemented (UNEP/CMS/ Resolution 9.19). Where possible negative impacts are likely but are difficult to prove, a precautionary approach is necessary (UNEP/CMS/ Resolution 9.19). Need for international, national and regional limitation of harmful underwater noise through management and regulation, where necessary (UNEP/CMS/ Resolution 10.24).			

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			Review potential benefits of "noise protection areas" (UNEP/CMS/ Resolution 9.19).				
OSPAR	EU Marine Strategy Framework Directive (MSFD) (2008/56/EC) requires all EU Member States to reach or maintain "good environmental status" by 2020. Indicator 11.2.1 of MSFD Descriptor 11: ambient noise level trends within the 1/3 octave bands 65 and 125 Hz measured by observation stations and/or with the use of models. Anthropogenic activities (shipping, military activities, construction, oil and gas exploration) increase underwater sound and can have negative impacts on marine life (OSPAR Agreement 2015-05). Recognize that underwater noise is one	Mitigation measures for underwater noise should be adjusted to match specific area- and project-related characteristics (OSPAR Commission 2014). Reduce source level and/or propagation of noise to areas and times of sensitive species absence (OSPAR Commission 2014). Analyze occurrence and seasonality of sensitive and/or protected marine species in areas of planned activities (OSPAR Commission 2014).	Monitoring underwater noise using sound maps generated from a combination of internationally agreed procedures for modeling and measurements (OSPAR Agreement 2015-05). Soundscape monitoring: use of arithmetic mean as it includes all sounds and is independent of snapshot duration (MSFD Technical Group on underwater noise; OSPAR Agreement 2015-05). Purpose of monitoring impulsive sound sources: quantify the pressure these sources exert on marine ecosystems and the spatio-temporal distribution of this pressure (OSPAR Agreement 2017-07).	Aim to keep levels of underwater noise that do not adversely affect the marine environment (OSPAR Agreement 2015-05). Consideration of monitoring of frequencies other than specified 63 and 125 Hz (OSPAR Agreement 2015-05). OSPAR should increase efforts to develop, review and apply mitigation measure to reduce impacts of anthropogenic underwater noise and develop guidance on best environmental practices and best available techniques for mitigating noise and its impacts (OSPAR 2010). Restriction of anthropogenic	Four-step process for modeling underwater noise: 1) *A priori* modeling, 2) Measurements for validation, 3) Iteratively combine modeling and measurement, and 4) Mature predictions that can be used as an input into the assessment of "good environmental status" (OSPAR Agreement 2015-05). To prevent injury, physical damage and death in marine mammals, use of Acoustic Deterrent Devices (ADDs) and/or Acoustic Harassment Devices (AHDs) (e.g. pingers or seal scarers) to displace animals from an area of harmful underwater noise	Use of alternative techniques with lower sound emissions or modification of operational state of noise source (e.g. reducing ship speed) (OSPAR Commission 2014).	Pile driving: pile diameter, soil structure, blow energy, size of hydraulic hammer, propagation by compression of the pile by the hammer strike, mitigate radiation into the water and seismic pathway, use of alternative foundation types (OSPAR Commission 2014 Annex I). Big bubble curtains: hole diameter and distance between individual holes, reduce air supply, use of double bubble curtain (OSPAR Commission 2014 Annex I). Little bubble curtains: layered

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	of the main pressures on the marine environment and noise levels are increasing internationally (OSPAR Commission 2014).		Spatio-temporal assessment unit used: Pulse Block Day. This is the number of days within a spatial unit in which anthropogenic impulsive sound sources occurred in a given calendar year (OSPAR Agreement 2017-07). Conduct Environmental Impact Assessments with respect to the planned activity (OSPAR Commission 2014). Noise propagation assessments included in environmental assessments (OSPAR Commission 2014 (2016 Update)).	underwater noise to a certain level (OSPAR Commission 2014). Predict possible underwater noise emissions of planned activities, and the cumulative effects of noise sources in an area (OSPAR Commission 2014). Recognize that industry-wide and individual company practices often supplement national guidelines (OSPAR Commission 2014 (2016 Update)). Mitigation for seismic surveys: exclusion zones, seasonal restrictions, presence of marine mammal observers, pre- and post-survey observation periods, soft start procedure, visual observation during operations, shut down procedures, passive acoustic monitoring, consideration of simultaneous and cumulative impacts	(OSPAR Commission 2014). Use of soft-start or ramp-up procedures to allow marine mammals to escape the area impacted by noise (OSPAR Commission 2014). Ensure marine mammal absence from the area of impact by using real-time (preferably) visual or acoustic monitoring with the aid of marine mammal observer and passive acoustic monitoring (OSPAR Commission 2014). Use of Acoustic Deterrent Devices (ADDs) introduces additional sound particularly at close range which could result in adverse effects including injury and possible habituation potentially resulting in chronic auditory damage (OSPAR Commission		ring systems, confined system, small bubble curtains with three or more compressors (OSPAR Commission 2014 Annex I). Isolation casings: steel casing with bubble curtain inside, double-walled plastic tube filled with polyurethane foam (OSPAR Commission 2014 Annex I). Hydro sound dampers/ “encapsulated bubbles” (OSPAR Commission 2014 Annex I). Vibropiling may have lower noise levels than impact piling but emits continuous sound (cannot be directly compared to impulsive sound) (OSPAR Commission 2014

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				(OSPAR Commission 2014 (2016 Update)). Advise operators to use airgun arrays at the lowest practicable volume (OSPAR Commission 2014 (2016 Update) Annex II).	2014 (2016 Update) Annex II). Potential alternatives to seismic airgun surveys: marine seismic vibroseis, "Teles", low-frequency acoustic sources, deep-towed acoustic/geophysical system, low impact seismic array, underwater tuneable organ-pipe, electromagnetic surveys, gravity and gravity gradiometry, shear wave generators (NCE 2007; CSA Ocean Sciences Inc. 2014; Cambridge Applied Physics Ltd. 2015).		Annex I). Drilled foundations, gravity base foundations, bucket foundations, floating wind turbines: construction/ installation noise, may have lower sound emissions than pile driving (OSPAR Commission 2014 Annex I). Additional noise mitigation concepts: high-frequency low energy piling, mandrel piles, slit piles (OSPAR Commission 2014 Annex I). Additional low-noise foundation concepts: silent pile driving (OSPAR Commission 2014 Annex I). Airguns: higher sensitivity hydrophones allow for the use of lower source levels and

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							narrower sound beams. Stationary fibre-optic receivers placed on the seafloor have greater sensitivity and signal to noise ratio (vs. towed streamer hydrophones). Ocean bottom node technology may reduce the distance the received signal has to travel (Castellote 2007; CSA Ocean Sciences Inc. 2014; OSPAR Commission 2014 (2016 Update) Annex II). Airguns: parabolic reflectors, "popcorn shooting" (OSPAR Commission 2014 (2016 Update) Annex II). Sound baffling: use of air bubbles as screens surrounding the seismic array (Castellote 2007).

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Recommendations and guidelines on anthropogenic underwater noise: Governmental Organizations

Governmental Organization	Awareness	Spatial and temporal mapping/management	Assessment/monitoring recommendations	General recommendations: Mitigation	Specific recommendations: Mitigation	General quieting technology recommendations	Specific quieting technology recommendations
European Union Marine Strategy Framework Directive (MSFD)	Marine mammals and other marine animals rely on sound for basic life functions and is crucial for their success and survival, making them sensitive to noise pollution (EU contribution to UN ICP). Anthropogenic underwater noise is increasing (EU contribution to UN ICP). High-intensity noises such as seismic surveys can cause permanent damage in marine animals, and continuous noises such as shipping may impact their behavior (EU contribution to UN ICP).	Criteria for "good environmental status": that the spatial distribution and temporal extent of both anthropogenic impulsive sound levels and anthropogenic continuous low-frequency sound levels in water do not affect populations of marine animals (EU Decision 2017/848).	EU Decision 2017/858 provides methodological standards and specifications for monitoring and assessment for both anthropogenic impulsive and continuous sound. Technical Group on underwater noise (2011), part of the Marine Strategy Framework Directive (MSFD) set up a register of loud impulsive noise and developed a joint monitoring program for continuous noise (EU contribution to UN ICP). Directive 2011/92/EU requires assessment of environmental effects and description of likely significant effects of certain public and private projects before projects are authorized.	Ensure that anthropogenic noise can be maintained at levels that do not cause harm to marine ecosystems (EU contribution to UN ICP). Consider the precautionary approach with regard to existing knowledge gaps (EU contribution to UN ICP). Directive 2008/56/EC of the European Parliament and of the Council requires EU Member States to achieve or maintain 'good environmental status' of marine waters by 2020 (based on 11 qualitative descriptors, of which one ensures that the "Introduction of energy, including underwater noise, is at levels that do not	Establish threshold values for both anthropogenic impulsive and continuous sound through cooperation at Union level (EU Decision 2017/858). AQUO project: assessment and mitigation of noise impacts from maritime transport on marine environment, providing policy guidelines (aquo.eu). SONIC project: developed tools to investigate and mitigate underwater noise effects from shipping (cordis.europa.eu). SILENV project: delivered "green label" proposal including recommended target noise levels and design guidelines (cordis.europa.eu).		LeanShips project (under Horizon 2020) combines technologies for efficient, less polluting vessels (leanships-project.eu). FIBRESHIP project works on Fibre-Reinforced Polymers in ship-building, which is expected to reduce noise pollution (fibreship.eu).

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				adversely affect the marine environment") (EU contribution to UN ICP). Framework Programme for Research and Innovation, Horizon 2020, is funding research on adverse impacts of anthropogenic underwater noise on marine environment to develop measures for noise reduction (ec.europa.eu/ programmes/ horizon2020).	COMMON SENSE project: provided cost-effective, multi-functional sensors to detect in-situ measurements of sound, usable across several platforms (commonsense project.eu). Current projects of Horizon 2020 for Societal Challenge 4 'Smart, Green and Integrated Transport' and Societal Challenge 3 'Secure, Clean and Efficient Energy', work on underwater noise mitigate and impact, and marine energy impacts, respectively (ec.europa.eu). BIAS (Baltic Sea Information on the Acoustic Soundscape) project: Estonia, Sweden, Finland, Poland, Germany and Denmark supported a regional assessment of underwater sound and ways to monitor noise across the Baltic Sea		

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					(bias-project.eu). HELCOM (Helsinki Commission: Denmark, Estonia, EU, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden) EN Noise group: development of underwater noise indicators and defining thresholds value for impulsive and continuous noise, underwater noise guidelines, and mapping ambient noise in the Baltic Sea.		
United States National Oceanic and Atmospheric Administration (NOAA) Ocean Noise Strategy (NOAA ONS Roadmap; see also: Harrison et al., 2016; Hatch et al., (2016).	NOAA Ocean Noise Strategy's goals: 1) NOAA management actions reduce chronic and cumulative effects of noise, 2) conduct research to fill critical gaps and best-informed management decisions, 3) develop publicly available tools to support assessment,	Improve management effectiveness for acoustic habitats through incorporation of place-based authorities (NOAA ONS Roadmap). Use National Marine Sanctuaries to maintain natural acoustic habitats (NOAA ONS Roadmap). Analyze marine species distributions, develop predictive sound field and exposure modeling for risk assessments and	Establish long-term recording assets, standardized acoustic monitoring and characterization of acoustic habitats (NOAA ONS Roadmap; Hatch et al., 2016). Enact monitoring requirements for compliance processes (NOAA ONS Roadmap). Real-time detection or marine species and anthropogenic activities	Development of national guidance for acoustic impact thresholds (NOAA ONS Roadmap). Need for a better understanding of noise impacts on reproductive success and survivorship to understand population-level impacts (NOAA ONS Roadmap). Maintain lower	Visual observers for protected species and/or passive acoustic technicians to limit acute impacts (NOAA ONS Roadmap). Increase understanding of presence, abundance and distribution of protected species and prey. In addition, their vulnerability and noise sensitivity, sound use, auditory thresholds, hearing mechanisms, behavioral sensitivity to	Expand existing international partnerships with regulated agencies and industries to promote use of quieter technologies (NOAA ONS Roadmap).	Use of sound attenuation methods for pile driving (e.g. bubble curtains, pile caps) (NOAA ONS Roadmap). Implement pilot programs for select shipping companies and select ports, with interests in supporting "green ship" development. Pilot programs would evaluate cost-recovery, consider

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	planning and mitigation for noise-generating activities, 4) promote public understanding of domestic and international noise impacts (Harrison et a., 2016). Increasing human activity is contributing to increasing levels of anthropogenic underwater noise, and has acute, chronic and cumulative impacts on marine animals and ecosystems (NOAA ONS Roadmap; Hatch et al., 2016). Marine Mammal Protection Act (MMPA): explicit protections and programs for all marine mammal species, stocks and their habitat. Endangered	mitigation planning (NOAA ONS Roadmap). Cetacean and Sound Mapping Project: develop tools to predict and map cumulative anthropogenic low-frequency underwater sound fields to manage noise impacts for cetacean species (cetsound.noaa.gov; NOAA ONS Roadmap). Seasonal/area limitations to avoid or reduce impacts in seasons or areas of biological importance (NOAA ONS Roadmap). Combine species distributions, species-specific acoustic sensitivities and sound maps to quantify risk (NOAA ONS Roadmap). Two general solutions for reducing spatio-temporal overlap of noise and marine animals: 1) real-time avoidance of overlap of sound and managed species, and 2) pre-planned larger-scale	(NOAA ONS Roadmap). Enhance efficacy and transparency of data-sharing and monitoring approaches/reports (NOAA ONS Roadmap; Hatch et al., 2016). Risk assessment: model sound propagation, marine animal sound exposure, ambient sound levels, noise-producing activities, and maintain standardized database for all data (NOAA ONS Roadmap). Risk assessments would include consideration of additional health and disease risks, where known and applicable to certain species (NOAA ONS Roadmap). Evaluation of noise impacts should not only include sound characteristics but other contextual factors (e.g. animal's activity state, novelty of a sound, relative spatial positions of the sound source and receiver) (NOAA ONS	background noise levels or reduce noise in areas of high density of acoustically sensitive species (NOAA ONS Roadmap). Promote public understanding, outreach efforts and engage with stakeholder to ensure that noise management implementation plans are effective and practicable (NOAA ONS Roadmap). Develop and support international initiatives to reduce influence from distant noise sources (NOAA ONS Roadmap). U.S. National Ocean Policy (Executive Order 13547 2010) firmly directs federal agencies to implement ecosystem-based management. Measures aimed at protecting aquatic	noise, baseline stress-markers and energetic information to link responses to sound to effects on survivorship and reproductive success (NOAA ONS Roadmap). Develop mechanisms to detect how multiple activities might contribute to the cumulative effect on individuals or a population (NOAA ONS Roadmap). Consultation authority can incentivize stakeholders to invest in mitigation techniques that could be used near sensitive or protected areas but is currently limited by staff capacity (NOAA ONS Roadmap). Apply consultation authority regarding recommendations, management goals, mitigation efforts and can help incentivize stakeholders to invest in new mitigation		integration of quieting goals with other environmental protection goals, and develop monitoring and docking incentives with participating ports (NOAA ONS Roadmap; Hatch et al., 2016).

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	Species Act (ESA): provide a means to conserve ecosystems of endangered and threatened species and provide a program for the conservation of those species. National Marine Sanctuaries Act (NMSA): protect special areas of the marine environment (e.g. due to their conservation, ecological, historical, scientific, cultural qualities). Magnuson-Stevens Fishery Conservation and Management Act (MSA): governs marine fisheries management, fostering long-term biological and economic sustainability. Marine animals	avoidance of sound use in important areas or times (NOAA ONS Roadmap).	Roadmap). Monitoring informed by: science and previous monitoring results, understanding of ecosystem function, and existing and ongoing studies and programs (NOAA ONS Roadmap). Develop transparent process to integrate incoming monitoring data and regularly review and adapt priority questions (NOAA ONS Roadmap). Noise impact assessments: identify 1) which species use or produce sound, 2) the role of sound in their life histories, and 3) the species' use of their environment (Hatch et al., 2016). Assessment via modeling of entire ecosystems to ensure that species-specific noise optimizations also benefit the habitat holistically (Hatch et al., 2016). Continued monitoring and	animal populations or species of high value: Fishery Management Plan action areas, Essential Fish Habitat, Cetacean Biologically Important Areas, Endangered Species' Critical Habitat, etc. (Hatch et al., 2016). Measures aimed at protecting aquatic areas of high value: Regional Marine Planning areas, Habitat Blueprint Focal Areas, National Resource Damage Assessment action areas, National Marine Sanctuaries, etc. (Hatch et al., 2016). Develop and support international initiatives to reduce impact from distant noise sources that may threaten highly migratory populations (Hatch et al., 2016). Address physical and behavioral affects from acute noise	techniques (Hatch et al., 2016). Underwater Sound Field Mapping Working Group (SoundMap): developed tools to spatially and temporally map human sound sources and their contribution to underwater ocean noise in US waters (Harrison et al., 2016; cetsound.noaa.gov). Cetacean Density and Distribution Mapping Working Group (CetMap): provide regional time- and species-specific density and distribution maps for cetaceans in US waters. CetMap also identified Biologically Important Areas (BIAs) including feeding and reproductive areas, migratory corridors, and areas where small and resident populations have been found (Harrison et al., 2016; cetsound.noaa.gov).		

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	not only use sound to communicate with conspecifics, but they also hear and respond to frequencies of other animals, which may be outside of the frequencies that they themselves produce (Hatch et al., 2016). Activities occurring outside sanctuary boundaries can have impacts inside sanctuary boundaries, which is often the case with noise (Hatch et al., 2016).		improvement (with new scientific information) of designated Cetacean Biologically Important Areas (Hatch et al., 2016). Metrics for how noise influences wildlife should identify protection targets, with respect to levels of biological effect, rather than noise levels as this is more relatable for to people and wildlife (Hatch et al., 2016).	exposure through noise-reduction techniques, reducing peak pressures or short-term accumulated energy (Hatch et al., 2016). Development of geospatial noise and noise-producing events registry may help address cumulative impacts (Hatch et al., 2016). Protect holistic acoustic conditions that animals rely on for survival and persistence. This necessitates international re-investment (Hatch et al., 2016).			

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Selected Best-Practice Publications for Mitigating Anthropogenic Noise

Selected best-practice publications	Awareness	Spatial and temporal mapping/management	Assessment/monitoring recommendations	General recommendations: Mitigation	Specific recommendations: Mitigation	General quieting technology recommendations	Specific quieting technology recommendations
Nowacek et al. (2015)	The expansion of seismic surveys necessitates greater regional and international dialogue, partnerships, and planning to manage potential environmental risks.	Identifies much larger spatial and temporal scales as being required for assessment, given seismic survey operations and potential effects such as masking being important considerations.	Broad scale monitoring approaches are recommended and, given the transboundary nature of noise, international regulatory instrument is recommended (under MARPOL).	Current exposure criteria are insufficient to consider the type and magnitude of acute and chronic impacts from seismic surveys; new approaches considering broader temporal and spatial scales and other effects are needed.	Risk assessment methods for evaluating noise impacts should be considered.	Highlights examples and approaches to noise reduction in other applications. Encourages incentive-based methods to encourage the commercial development and application of quieting technologies.	
Nowacek and Southall (2016).	Identifies a variety of environmental concerns regarding seismic surveys, particularly in sensitive marine habitat areas. Recognizes that there is a long planning horizon and a large degree of predictability in terms of steps and technologies used. Recommends broad practices and specific	Also identifies that there is a much broader spatial and temporal scale required for evaluating potential impacts from individual seismic surveys and especially overlapping/aggregate survey activity than has previously been identified.	Proposes a comprehensive, iterative, and adaptive process for planning, implementing, and evaluating impacts from seismic surveys. Identifies need for transparency in processes and the need for multi-stakeholder awareness. Monitoring protocols should be developed for all sensitive/protected	Identifies a structures risk assessment-based approach to monitoring and mitigation with the following elements: * evaluation of risks of proposed actions and alternatives, based on survey characteristics, and environmental and biological/ecological characteristics; identification of mitigation actions, including specific	Specific monitoring and mitigation objectives identified are: * operational implementation of mitigation measures, giving consideration to the timing of the survey and source characteristics; * implementation of real-time	Highlights examples and approaches to noise reduction in other applications.	

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	steps within each in assessment, mitigation, monitoring, and evaluation/improvement for responsibly managing seismic surveys.		species and integrated with real-time mitigation, and should include a comprehensive reporting plan.	mitigation objectives, operational protocols for the detection of sensitive species, and training and coordination for relevant personnel; and * development of monitoring strategy and methods for application before, during, and following operations	mitigation, including written protocols and a dedicated effort by properly trained personnel; and * implementation of monitoring protocols with data validation and archiving, to allow for effective post-survey reporting and evaluation.		

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