Integrating Bioacoustics and International Water Law for Assessing the Behavioral Impacts of Underwater Noise on Cetaceans: Towards Private Governance & Enhanced Conservation Strategies

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Introduction: Addressing the Impact of Underwater Noise Pollution on Cetaceans

Underwater noise pollution has emerged as one of the most significant and insidious threats to marine biodiversity, particularly impacting cetacean populations, including whales, dolphins, and porpoises.[1] Unlike traditional forms of pollution that are visible, noise pollution in the marine environment is largely invisible but can have far-reaching and destructive effects on marine life.[2] The primary sources of underwater noise pollution are human activities, including commercial shipping, naval sonar operations, oil and gas exploration, and industrial fishing practices. These activities generate high-intensity noise that disrupts essential life functions of marine animals,[3] especially cetaceans, which rely heavily on sound for communication, navigation, and hunting.[4]

Cetaceans use echolocation—sound waves—to navigate vast oceanic spaces, locate prey, and communicate with one another. These vocalizations, including clicks, whistles, and pulses, form the foundation of their social interactions and foraging strategies. The disruption of this acoustic environment due to underwater noise pollution can cause immediate and severe consequences. High levels of noise from ships, military sonar, and seismic surveys can lead to disorientation,[5] physical harm such as hearing loss, and stress-induced behavioral changes. These disturbances can interfere with the cetaceans' ability to communicate, navigate, and locate food, thereby affecting their overall health, reproductive success, and survival rates.[6] Furthermore, sustained exposure to chronic noise pollution can lead to displacement from critical habitats, leaving these animals vulnerable to further threats.

In addition to its direct impacts on cetaceans, noise pollution also reverberates throughout the broader marine ecosystem. Cetaceans are apex predators, playing a critical role in maintaining the balance of marine ecosystems. Their decline due to noise pollution has cascading effects on

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[1] National Oceanic and Atmospheric Administration, Ocean Noise, NOAA Fisheries, https://www.fisheries.noaa.gov/national/science-data/ocean-noise

[2] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf

[3] Engell-Sørensen, K., et al.,"Evaluation of the Effect of Noise from Offshore Pile-Driving on Marine Fish", Bio/consult as, Johs. Ewaldsvej 42-44

[4] McKenzie-Maxon, C.,"Offshore Wind Turbine Construction, Offshore Pile-Driving Underwater and Above Water Noise Measurement and Analysis., Rep. to: SEAS Distribution

[5] ICES. 1995. Underwater noise of research vessels: review and recommendations. ICES Cooperative Research Report, Vol. 209. 65 pp. https://doi.org/10.17895/ices.pub.5317

[6] M.A. McDonald, J. Calambokidis, A.M. Teranishi & J.A. Hildebrand, The Acoustic Calls of Blue Whales off California with Gender Data, 109 J. Acoust. Soc. Am. 1728 (2001).

the entire food web.[7] As cetacean populations diminish, they disrupt the abundance and behavior of other marine species—including fish stocks—which leads to imbalances in marine food chains. These disruptions can result in the decline of essential marine resources, further compounding the ecological consequences of noise pollution.[8]

The sources of underwater noise pollution are diverse and include commercial shipping, naval sonar, seismic surveys for oil and gas exploration, and offshore construction activities.[9] Shipping traffic, particularly in busy maritime corridors, is one of the largest contributors to chronic noise pollution, with ships' engines, propellers, and hulls producing constant sound. Naval activities, including military sonar, can create intense bursts of noise that disorient and disturb cetaceans, interfering with their ability to communicate, navigate, and hunt.[10] Seismic surveys, which use underwater explosions to map the ocean floor, also emit powerful sound waves that can cause hearing damage and disrupt marine life. These sources of noise pollution are widespread, making it difficult to regulate and mitigate their effects on marine ecosystems.[11]

Despite mounting empirical evidence linking underwater noise pollution to adverse outcomes for cetaceans—such as increased strandings and the disruption of migratory patterns—the regulatory frameworks addressing this issue remain insufficient. While international treaties such as the United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Migratory Species (CMS) lay out general principles for marine conservation and the protection of migratory species like cetaceans, enforcement remains a significant challenge.[12] UNCLOS provides guidelines for the protection of marine environments and the prevention of pollution, while CMS emphasizes the conservation of migratory species across borders. However, inconsistencies in compliance and enforcement hinder the effectiveness of these instruments, especially in international waters, where legal jurisdiction can be ambiguous, and political will varies among nations.[13]

Regulatory bodies like the International Maritime Organization (IMO) and initiatives such as the Marine Strategy Framework Directive (MSFD) have attempted to address the issue of

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[7] A. Širović, J.A. Hildebrand, S.M. Wiggins & D. Thiele, Blue and Fin Whale Acoustic Presence Around Antarctica During 2003 and 2004, 25 Mar. Mamm. Sci. 125 (2009).

[8] Erbe, C., Underwater Noise of Whale-Watching Boats and Potential Effects on Killer Whales (Orcinus orca), Based on an Acoustic Impact Model, 18 Mar. Mamm. Sci. 394 (2002).
[9] Erbe, C. & Farmer, D.M., Masked Hearing Thresholds of a Beluga Whale (Delphinapterus leucas) in Icebreaker Noise, 45 Deep Sea Res. II Top. Stud. Oceanogr. 1373 (1998).
[10] Ross, D., Mechanics of Underwater Noise (Pergamon Press 1976).
[11] Lucke, K., Siebert, U., Lepper, P.A., & Blanchet, M.A., Temporary Shift in Masked Hearing Thresholds in a Harbor Porpoise (Phocoena phocoena) After Exposure to Seismic Airgun Stimuli, 125 J. Acoust. Soc. Am. 4060 (2009).
[12] Nat'l Research Council, Marine Mammals and Low-Frequency Sound (Nat'l Academies Press 2000).
[13] Finley, K.J., Miller, G.W., Davis, R.A., & Greene, C.R., Reactions of Belugas (Delphinapterus leucas) and Narwhals (Monodon monoceros) to Ice-Breaking Ships in the Canadian High Arctic, 224 Can. Bull. Fish. Aquat. Sci. 97 (1990).

underwater noise pollution, but these efforts have proven inadequate.[14] For instance, existing regulations focus primarily on shipping traffic and the prevention of noise in certain regions, but they fail to comprehensively address other significant sources of underwater noise, such as naval activities or oil and gas exploration. The challenges associated with enforcing noise reduction measures are further exacerbated by gaps in the scientific understanding of noise's full impacts, particularly regarding long-term behavioral effects on cetaceans.[15] Many scholars have also noted the shortcomings of international marine conservation law, arguing that current legal frameworks fail to effectively mitigate the diverse and widespread sources of underwater noise. These critiques emphasize the need for more comprehensive, enforceable measures that account for all anthropogenic noise sources, promote greater international cooperation, and incorporate the latest scientific findings on marine ecosystems and cetacean health.[16]

Another notable shortcoming of international marine conservation is its inequitable distribution of benefits and burdens. As Pat Parenteau[17] has noted, developing countries often bear the greatest environmental impacts while lacking the resources to effectively address them. The need for more robust legal frameworks that effectively address underwater noise pollution is further emphasized by the disproportionate impacts on countries with fewer resources to address such issues. For example, nations like Pakistan[18]—where marine ecosystems are vital for the livelihoods and cultural practices of coastal communities—often lack the regulatory infrastructure to adequately manage noise pollution. In these regions, the failure to control industrial activities and their impacts on marine life has significant consequences, not only for biodiversity but also for the health and sustainability of local communities. The international community's approach to noise pollution must thus account for global equity, recognizing that lower-income nations often bear the brunt of environmental degradation despite having fewer resources to manage these challenges.[19]

Existing scholarship on marine conservation law has extensively discussed the challenges of addressing underwater noise pollution and the limitations of the current international legal regime. Many scholars have highlighted the inadequacies of existing legal frameworks, arguing that they fail to address the diverse and often overlapping sources of marine noise pollution. The shortcomings of these frameworks stem from a lack of coordination among international bodies, inconsistent enforcement, and the absence of comprehensive regulations that account for all

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[14] Tasker, M.L., Amundin, M., Andre, M., Hawkins, A., Lang, W., Merck, T., Scholik-Schlomer, A., Teilmann, J., Thomsen, F., Werner, S., & Zakharia, M., MSFD Task Group 11 Report: Underwater Noise and Other Forms of Energy, EUR 24341 EN (European Commission Joint Research Centre 2010).
[15] Erbe, C., Underwater Noise of Whale-Watching Boats and Potential Effects on Killer Whales (Orcinus orca), Based on an Acoustic Impact Model, 18 Mar. Mamm. Sci. 394 (2002).
[16] Lucke, K., Siebert, U., Lepper, P.A., & Blanchet, M.A., Temporary Shift in Masked Hearing Thresholds in a Harbor Porpoise (Phocoena phocoena) After Exposure to Seismic Airgun Stimuli, 125 J. Acoust. Soc. Am. 4060 (2009).
[17] Parenteau, Pat. "Now the Hard Part: Environmental Advocacy in the 21st Century." Vermont Law School's Environmental Law Center, 13 Sept. 2022.
[18] Id. Mention of Pakistan's 2021 and 2022 urban flooding and the country being a small contributor to the world's CO2 levels.
[19] Lucke, K., Siebert, U., Lepper, P.A., & Blanchet, M.A., Temporary Shift in Masked Hearing Thresholds in a Harbor Porpoise (Phocoena phocoena) After Exposure to Seismic Airgun Stimuli, 125 J. Acoust. Soc. Am. 4060 (2009).

sources of noise, from commercial shipping to naval activities. These critiques point to a broader issue in international environmental law: the difficulty in creating enforceable regulations that adequately protect marine ecosystems while balancing economic interests.

Further complicating these issues are the specific challenges faced by developing countries, which often lack the resources and infrastructure to manage the impacts of environmental degradation. Scholarship on the inequities of international environmental law, particularly through the lens of Environmental Justice (EJ) and Public Environmental Governance (PEG), has brought attention to the disproportionate burden that lower-income nations bear in the face of environmental harms. Developing countries like Pakistan, where marine ecosystems are vital for local livelihoods, often struggle to address noise pollution due to a lack of regulatory frameworks and capacity.[20] EJ scholars emphasize how international law fails to account for these inequities, reinforcing the need for a more inclusive and equitable approach to marine conservation. As scholars in PEG have suggested, the incorporation of local communities and stakeholders in environmental governance is essential to developing effective solutions that both protect the environment and ensure the social and economic sustainability of vulnerable populations.[21]

In light of these critiques, several scholars have proposed new frameworks and legal approaches that may offer solutions to these challenges. For example, PEG scholarship suggests that a shift toward more decentralized, locally informed governance could help bridge the gap in capacity and enforcement.[22] Similarly, EJ scholarship advocates for a more inclusive approach that incorporates the voices of marginalized communities in global environmental decision-making. These ideas point to a need for new legal mechanisms that can address the shortcomings of current international law and offer more equitable solutions for developing nations.[23]

One promising avenue to mitigate the effects of underwater noise pollution is the integration of bioacoustic research with international marine law. While bioacoustic methodologies, such as passive acoustic monitoring (using hydrophones to listen to marine sounds) and active acoustic techniques (using sonar systems to measure soundscapes), have been in use for some time, their widespread application within legal frameworks is still limited.[24] These methods are critical tools for measuring ambient noise levels in marine environments and assessing the impact of noise on cetacean behavior. However, their integration into existing legal frameworks has been slow, in part due to challenges in standardizing data collection and analysis, as well as the complexities of applying scientific findings within the context of international law. Despite the increasing

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[20] Lucke, K., Siebert, U., Lepper, P.A., & Blanchet, M.A., Temporary Shift in Masked Hearing Thresholds in a Harbor Porpoise (Phocoena phocoena) After Exposure to Seismic Airgun Stimuli, 125 J. Acoust. Soc. Am. 4060 (2009).

[21] Finley, K.J., Miller, G.W., Davis, R.A., & Greene, C.R., Reactions of Belugas (Delphinapterus leucas) and Narwhals (Monodon monoceros) to Ice-Breaking Ships in the Canadian High Arctic, 224 Can. Bull. Fish. Aquat. Sci. 97 (1990).

[22] U.S. Dep't of the Navy, Atlantic Fleet Active Sonar Training Environmental Impact Statement/Overseas Environmental Impact Statement, available at http://afasteis.gcsaic.com/docs.aspx (last visited Apr. 5, 2010).
[23] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf
[24] Id.

availability of advanced data analysis techniques, which can map soundscapes and analyze changes in cetacean vocalizations and behaviors, policymakers have not fully incorporated these technologies into regulatory systems. This lag can be attributed to factors such as insufficient collaboration between scientific and legal communities, lack of funding for comprehensive monitoring programs, and the inertia of established legal regimes that often struggle to adapt to new, rapidly evolving technologies. By combining bioacoustic data with legal frameworks, stakeholders can better assess the effectiveness of existing regulations and develop more targeted strategies for noise management.[25]

However, challenges remain in integrating bioacoustic data into legal frameworks and ensuring that this data is used to improve regulatory responses. Legal and policy constraints, such as jurisdictional ambiguities, limited enforcement, and international cooperation hurdles, complicate the development of cohesive noise management strategies. Ethical considerations regarding the impact of noise monitoring on cetaceans and the scientific uncertainties surrounding the long-term effects of noise exposure further complicate conservation efforts.[26]

To overcome these barriers, a multi-pronged approach is needed. First, international legal frameworks must evolve to incorporate standardized bioacoustic monitoring techniques, ensuring consistent data collection across jurisdictions. Collaboration between scientists, policymakers, and legal experts is crucial to design regulations that are adaptable and capable of addressing the complexities of marine noise pollution. Addressing ethical concerns will also require the development of guidelines for responsible and non-invasive monitoring practices, ensuring that research does not itself harm cetaceans. [27] Additionally, strengthening international cooperation, with clear enforcement mechanisms and global agreements, will provide the necessary support to address the transboundary nature of noise pollution. Public awareness campaigns highlighting the impacts of underwater noise on cetaceans and marine ecosystems will be instrumental in creating political will and fostering a culture of conservation. Ultimately, a more integrated and responsive regulatory framework will be key to addressing the challenges of marine noise pollution.

The Science Behind the Problem.

The issue primarily stems from human activities such as shipping, military operations, and industrial endeavors, which interfere with the natural communication and echolocation abilities of marine mammals. Cetaceans rely on vocalizations, including clicks and whistles, for social interaction, navigation, and hunting, and any disruption can lead to detrimental changes in their behavior, reproductive success, and overall health.[28] High-intensity noise can cause immediate

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[25] Erbe, C. & Farmer, D.M., Masked Hearing Thresholds of a Beluga Whale (Delphinapterus leucas) in Icebreaker Noise, 45 Deep Sea Res. II Top. Stud. Oceanogr. 1373 (1998).

[26] Finley, K.J., Miller, G.W., Davis, R.A., & Greene, C.R., Reactions of Belugas (Delphinapterus leucas) and Narwhals (Monodon monoceros) to Ice-Breaking Ships in the Canadian High Arctic, 224 Can. Bull. Fish. Aquat. Sci. 97 (1990).

[27] David P. Daniels et al., Public Opinion on Environmental Policy in the United States, in THE OXFORD HANDBOOK OF U.S. ENVIRONMENTAL POLICY 461, 467–70 (Sheldon Kamieniecki & Michael E. Kraft eds., 2013)

[28] Finley, K.J., Miller, G.W., Davis, R.A., & Greene, C.R., Reactions of Belugas (Delphinapterus leucas) and Narwhals (Monodon monoceros) to Ice-Breaking Ships in the Canadian High Arctic, 224 Can. Bull. Fish. Aquat. Sci. 97 (1990).

physical harm, including hearing loss, further compounding the challenges these species face..[29] Despite growing awareness and empirical evidence linking noise pollution to adverse cetacean outcomes—such as increased strandings associated with naval exercises—[30]the regulatory frameworks addressing these issues remain inadequate.[31]

Specifically, Cetaceans, which include dolphins, whales[32], and porpoises, rely on sound for nearly all aspects of their life. Echolocation and acoustic communication are crucial for navigation, hunting, and maintaining social structures. Excessive noise levels interfere with these processes, leading to disorientation, stress, and in severe cases, strandings and mortality.[33] This has been seen as an international occurrence. A case study in the North Atlantic documented a 40% reduction in feeding efficiency for humpback whales in areas exposed to seismic surveys. In Pakistan's Arabian Sea, industrial activities have intensified over the past decade, coinciding with a decline in cetacean populations. Bioacoustic surveys conducted by WWF-Pakistan report a significant reduction in dolphin pods near major shipping lanes.[34]

International water law, particularly instruments like the United Nations Convention on the Law of the Sea (UNCLOS) and the Convention on Migratory Species (CMS), provides a basis for marine conservation and pollution management. While UNCLOS delineates state responsibilities concerning marine pollution and biodiversity protection, the CMS emphasizes the conservation of migratory species, including cetaceans.[35] However, enforcement remains a critical challenge, especially in international waters where compliance varies significantly among nations. Regulatory bodies such as the International Maritime Organization (IMO) and directives like the

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[29] Guan, S. and Brookens, T. (2021) The use of psychoacoustics in Marine Mammal Conservation in the United States: From science to management and policy, MDPI. Available at: https://www.mdpi.com/2077-1312/9/5/507

[30] A case in point is the increased incidences of mass strandings of whales attributed to naval sonar activities. Such strandings are not only a tragic loss of biodiversity but also indicative of severe ecological stress. In regions like the Arabian Sea, where local communities coexist with marine life, these events disrupt both natural ecosystems and human livelihoods.

[31] André, M. et al. (2014) Best practices in management, assessment and control of Underwater Noise Pollution, Pàgina inicial de UPCommons. Available at: https://upcommons.upc.edu/handle/2117/22457

[32] International Whaling Commission (IWC), 2021 Report on Marine Noise Pollution, available at iwc.int/reports.

[33] Harris, B.A. (2017) Turn down the volume: Improved Federal Regulation of shipping noise is necessary to protect marine mammals.

[34] K Mehboob and SM Shahzad, Sustainable Management of Marine Fisheries Resource: An overview. https://www.researchgate.net/publication/324861546_Sustainable_Management_of_Marine_Fisheries_Resource_An_Overview

[35] Convention on Migratory Species, CMS. https://www.cms.int/sites/default/files/document/ScC16_Doc_19_Rev2_Draft_Proposals_Tiger_Eonly_0.pdf

Marine Strategy Framework Directive (MSFD) attempt to mitigate underwater noise pollution, yet their implementation is often faced with difficulties, which in turn highlights the urgent need for more effective legal instruments.[36]

Additionally, the physiological impact of noise pollution on cetaceans cannot be understated. Prolonged exposure to high decibel sound waves has been linked to auditory damage, increased stress hormone levels, and behavioral shifts such as avoidance of otherwise critical feeding grounds.[37] Recent research from marine biology journals highlights the cascading effects of such disruptions, with declines in cetacean populations leading to reduced predation on forage fish and subsequent imbalances in marine food webs.

Pakistan's Legal Obligations Under International Law

As a member of the international community, Pakistan is bound by various legal obligations related to marine conservation under international law. One of the primary frameworks for marine protection is the UNCLOS, to which Pakistan is a signatory. Article 194 of UNCLOS addresses the Protection and Preservation of the Marine Environment, outlining the duty of signatory states to follow specific rules and guidelines to protect the marine environment. [38] Part 1 of Article 194 explicitly states that states must "prevent, reduce, and control pollution of the marine environment," which includes underwater noise pollution—an often overlooked aspect in international discourse.[39] This highlights the importance of addressing the full scope of marine pollution, including its impact on marine life, especially species like cetaceans. [40]

Furthermore, UNCLOS emphasizes the need for cooperation among neighboring states in the conservation of marine species and the protection of the marine environment. The Exclusive Economic Zones (EEZs) of neighboring countries such as Iran and India are inherently linked to Pakistan's efforts, as the health of marine ecosystems and the sustainability of fisheries in Pakistan's EEZ are affected by the policies and practices of its neighbors.[41]

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[36] Merchant, N.D. (2018) Underwater noise abatement: Economic factors and Policy Options, Environmental Science & Policy. Available at: https://www.sciencedirect.com/science/article/pii/S1462901118310748

[37] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf

[38] Preamble to the United Nations Convention on the law of the sea, United Nations. Available at: https://www.un.org/depts/los/convention_agreements/texts/unclos/part12.html

[39] Michelle Baldwin, Elizabeth C. Davis & Brett D. Witham, Review of Developments in Ocean and Coastal Law 1999-2000: Recent Developments, 31 Tulsa L. Rev. 367 (2000).

[40] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf.

[41] Id.

Pakistan's legal obligations are also detailed in its submissions to UNCLOS, which include a map that delineates the outer limits of its continental shelf. [42] The coordinates on this map are defined by straight lines not exceeding 60 nautical miles in length, connecting fixed points. This demarcation is crucial because Pakistan's EEZ is a vital area for marine biodiversity and supports significant economic activities such as shipping and fishing.[11] In line with its obligations, Pakistan is responsible for regulating activities within its EEZ, including managing shipping speeds and frequencies, to mitigate the impacts of underwater noise pollution, which can harm marine life. These measures are necessary to fulfill Pakistan's obligations under international law to protect marine resources and ensure the sustainable use of its waters.

Pakistan is also a party to international agreements that promote sustainable fisheries management, such as those established by the Food and Agriculture Organization (FAO). These frameworks encourage science-based approaches to managing marine ecosystems and mitigating threats to biodiversity. Despite these international commitments, Pakistan faces challenges in fully implementing these regulations, largely due to gaps in national enforcement mechanisms and the lack of sufficient resources for monitoring and compliance. [43]

International water law, particularly instruments like UNCLOS and the Convention on Migratory Species (CMS), provides the foundation for marine conservation and pollution management. While UNCLOS outlines state responsibilities for marine pollution and biodiversity protection, the CMS specifically focuses on cetaceans. However, the effectiveness of these international agreements is often undermined by challenges in enforcement, particularly in international waters, where compliance with regulations varies significantly among nations. While organizations like the International Maritime Organization (IMO) and initiatives such as the Marine Strategy Framework Directive (MSFD) aim to mitigate underwater noise pollution, their implementation is often inconsistent, highlighting the need for more effective legal instruments and enforcement mechanisms.[44]

The integration of bioacoustic methodologies into international water law offers a significant opportunity to improve marine conservation efforts. Passive acoustic monitoring using hydrophones and active acoustic techniques, such as sonar systems, are essential tools for measuring ambient noise levels and monitoring cetacean vocalizations.[45] These techniques enable the detection of soundscape changes in marine environments and the behavioral impacts

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[42] UN. Available at: https://digitallibrary.un.org/nanna/record/1650694/files/A_HRC_RES_39_12-EN.pdf?withWatermark=0&withMetadata=0&version=1&registerDownload=1

[43] UN. Map: https://www.un.org/depts/los/LEGISLATIONANDTREATIES/PDFFILES/DEPOSIT/pak_mzn122_2016_chart.pdf

[44] U.N. Env't Programme, Annex: Adverse Impacts of Anthropogenic Noise on Cetaceans and Other Migratory Species, available at https://www.cms.int/en/document/annex-adverse-impacts-an-thropogenic-noise-cetaceans-and-other-migratory-species

[45] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf

on cetaceans exposed to noise pollution. By integrating bioacoustic data into regulatory assessments, stakeholders can better understand the effectiveness of existing policies and propose necessary adjustments to strengthen conservation efforts.[46]

Pakistan's obligations under UNCLOS are critical in this context. With its significant coastline and EEZ, Pakistan plays an essential role in protecting the marine environment and regulating noise pollution within its waters. The regulation of underwater noise is particularly important given the reliance of cetaceans on vocalizations for communication, navigation, and hunting. Noise pollution from shipping, military activities, and industrial operations can disrupt these vital behaviors, leading to harmful consequences for cetacean populations. Thus, Pakistan must enhance its efforts to align national policies with international legal frameworks that aim to address the impacts of noise pollution.

The global issue of underwater noise pollution is not isolated to one country, and the shared responsibility among nations, particularly in regions with overlapping EEZs, is crucial for effective conservation.[47] The cooperation of countries like Pakistan, India, and Iran is essential in managing and reducing noise pollution in the shared marine environment. Given the interconnectedness of marine ecosystems, effective governance requires joint efforts to monitor and regulate activities that contribute to underwater noise, such as shipping and naval operations.[48]

Pakistan's regulatory frameworks for addressing underwater noise pollution are still developing. As a signatory to UNCLOS, Pakistan has an obligation to take all necessary measures to prevent, reduce, and control pollution in its EEZ, including noise pollution. However, there are challenges in enforcing these measures due to a lack of sufficient resources, technical expertise, and effective monitoring systems. This gap in enforcement capacity underscores the importance of strengthening national legal frameworks and improving international cooperation on marine conservation.

In terms of comparative analysis, Pakistan lags behind countries like the United States, which has a more robust legal framework for regulating underwater noise pollution. U.S. laws, such as the Marine Mammal Protection Act (MMPA) and the National Environmental Policy Act (NEPA), set specific noise thresholds and regulations to protect marine mammals from the harmful effects of anthropogenic noise.[49] In contrast, Pakistan's regulatory capacity to enforce such measures remains underdeveloped. This disparity in enforcement highlights the need for

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[46] Wysocki, L.E., Dittami, J.P., & Ladich, F., Ship Noise and Cortisol Secretion in European Freshwater Fishes, 128 Biol. Conserv. 501 (2006), https://doi.org/10.1016/j.biocon.2005.10.020

[47] Alski, J.R., Pearson, W.H., & Malme, C.I., Effects of Sounds from a Geophysical Survey Device on Catch-Per-Unit-Effort in a Hook-and-Line, (1992).

[48] Taylor, B.L., Martinez, M., Gerrodette, T., Barlow, J., & Hrovat, Y.N., Lessons from Monitoring Trends in Abundance of Marine Mammals, 23 Mar. Mamm. Sci. 157 (2007), https://doi.org/10.1111/j.1748-7692.2006.00092.x.

[49] Williams, R., Wright, A.J., Ashe, E., Blight, L.K., Bruintjes, R., Canessa, R., Clark, C.W., Cullis-Suzuki, S., Dakin, D.T., Erbe, C., Hammond, P.S., Merchant, N.D., O'Hara, P.D., Purser, J., Radford, A.N., Simpson, S.D., Thomas, L., & Wale, M.A., Impacts of Anthropogenic Noise on Marine Life: Publication Patterns, New Discoveries, and Future Directions in Research and Management, 115 Ocean & Coast. Manag. 17 (2015), https://doi.org/10.1016/j.ocecoaman.2015.05.021.

more concerted international efforts to ensure that countries with limited resources can effectively address the challenges posed by underwater noise pollution.

To address these challenges, it is essential to advocate for stronger international legal frameworks that specifically target underwater noise pollution. This could include developing binding agreements among nations that regulate noise pollution across borders, especially in areas with high levels of international shipping and military activity. Furthermore, integrating bioacoustic data into international marine conservation policies would enable more precise monitoring and more targeted interventions to protect cetacean populations from noise-related disturbances.

International Approaches to Underwater Noise Pollution: Lessons from the United States and the European Union

Globally, countries have made significant strides in addressing underwater noise pollution. In the United States, the National Oceanic and Atmospheric Administration (NOAA) has introduced measures to reduce the noise generated by commercial shipping.[50] These measures include reducing ship speeds in critical habitats for endangered species, like the North Atlantic right whale, and investing in research to understand how noise impacts marine mammals. Although this approach has yielded some progress, much remains to be done to fully mitigate the impacts of underwater noise. The US has tailored marine practices such as reducing ship speed significantly decreases noise levels.[51] A container ship traveling at 25 knots can cut its acoustic footprint by nearly 80% by slowing to 20 knots.[52] These minor changes could be integrated into shipping law and policies to take better measure.

Similarly, the European Union (EU)[53] has taken a coordinated approach through its Marine Strategy Framework Directive (MSFD). This directive aims to reduce the impact of human activities, including noise pollution, on marine ecosystems. The EU has established guidelines for monitoring underwater noise levels[54] and mitigating its effects on marine biodiversity. Member states are encouraged to assess and manage noise levels in their waters to maintain the ecological health and resilience of European seas.

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[50] Merchant, N.D. (2018) Underwater noise abatement: Economic factors and Policy Options, Environmental Science & Policy. Available at: https://www.sciencedirect.com/science/article/pii/S1462901118310748

[51] Lindsay I. McCarl, Untethering UMVs from Vessels: Why the United States Should Construct a New Environmental Legal Scheme for Unmanned Maritime Vehicles, 127 Dick. L. Rev. 469 (2023).

[52] Williams, R. et al. (1970) Chronic ocean noise and cetacean population models, Welcome to the NOAA Institutional Repository. Available at: https://repository.library.noaa.gov/view/noaa/63434 (Accessed: 01 December 2024). Pg 88, Para 3).

[53] EU Marine Strategy Framework Directive, 'Reducing NoisePollution in Shared Waters,' 2020, available at europa.eu.

[54] Establishing acoustic monitoring stations along key shipping routes and near fishing zones can provide valuable data for regulatory enforcement. Such programs should be funded through partnerships, with shipping companies contributing under the 'polluter pays' principle.

The lessons from the United States and the EU provide a valuable roadmap for Pakistan, offering strategies for monitoring and reducing noise pollution, fostering international cooperation, and balancing environmental and economic interests. For these global efforts to be successful, they must be complemented by stronger collaborations between governments, industries, and local communities.[55]

The Gap Between Public Governance and the Role of Private Governance in the matter

Environmental law has gradually evolved from being primarily based in administrative law to also being significantly influenced by private law and private governance.[56] Despite the extensive body of international and regional legal instruments aimed at protecting marine biodiversity, the enforcement of underwater noise pollution regulations remains problematic. This issue is particularly stark in countries with limited regulatory capacity, such as Pakistan, which struggles to implement the same level of marine protection as seen in countries like the United States. Furthermore, there is a lack of global consensus on noise thresholds and compliance mechanisms, and the variability in national enforcement exacerbates the problem. This governance gap highlights the need for innovative solutions beyond traditional state regulatory frameworks. One such solution is private governance, where businesses and industries proactively address environmental issues, including underwater noise pollution, through self-regulation and voluntary standards.[57] This approach not only provides an opportunity to fill gaps left by governmental efforts but could also drive more effective and widespread marine conservation efforts. The following discussion explores how private governance can address the challenges of underwater noise pollution, offering potential solutions through industry collaboration, technological innovation, and market-driven incentives.

i. Role of Private Governance in Underwater Noise Pollution

In the context of underwater noise pollution, private governance could take the form of industry-led standards and self-regulation within the maritime and energy sectors. By adopting noise-reduction technologies, monitoring and reporting practices, and eco-friendly operational standards, private actors can reduce the harmful impacts of their activities on cetaceans without waiting for slow-moving legislative processes.[58] Through voluntary compliance with best practice standards and certification programs, private entities can show leadership in marine

[55] Food & Agric. Org. of the U.N., The State of World Fisheries and Aquaculture 2016: Contributing to Food Security and Nutrition for All (2016).
[56] Michael P. Vandenbergh, Private Environmental Governance, 99 Cornell L. Rev. 129 (2013) Available at: http://scholarship.law.cornell.edu/clr/vol99/iss1/3
[57] U.S. Dep't of the Navy, Atlantic Fleet Active Sonar Training Environmental Impact Statement/Overseas Environmental Impact Statement, available at http://afasteis.gcsaic.com/docs.aspx (last visited Apr. 5, 2010).
[58] Galperin, Joshua, Governing Private Governance (October 31, 2023). 56 Az. St. L.J. 765 (2024), Available at SSRN: https://ssrn.com/abstract=4619248 or http://dx.doi.org/10.2139/ssrn.4619248

conservation, sometimes surpassing governmental efforts.[59] This proactive stance would not only protect marine life but also enhance the long-term sustainability of industries that rely on healthy oceans, such as fisheries and tourism.

ii. Integrating Bioacoustic Data into Conservation Efforts

Integrating bioacoustic data into conservation efforts is a crucial aspect of effective private governance. Technologies like hydrophones and passive acoustic monitoring allow for real-time measurement of ambient noise levels and cetacean vocalizations, providing data that can inform policy and operational changes. This technology enables the identification of noise hotspots and the assessment of its impact on cetacean behavior, health, and reproductive success. Private companies could adopt bioacoustic monitoring to measure the effects of their activities on marine life, ensuring that their operations stay within safe noise limits. This could be done through self-regulation or industry-wide initiatives, with third-party verification from environmental organizations to ensure transparency.

iii. Industry Examples of Private Governance

For example, shipping companies could implement regular noise audits and take steps to retrofit ships with quieter propulsion technologies. Likewise, offshore oil and gas operations could install noise-reducing technologies on drilling platforms and sonar systems.[60] By incorporating bioacoustic monitoring into their operational protocols, industries can demonstrate their commitment to sustainable practices and be more accountable to both regulators and the public. The goal would be to create a system where environmental protection becomes a market-driven initiative, making it profitable for companies to invest in cetacean-friendly technologies and practices.[61]

iv. Market-Based Incentives and Regulatory Pressure

A core principle of private governance is that the market can be incentivized to drive environmental responsibility. In the case of cetacean protection, this could be achieved through a combination of market-based incentives and regulatory pressure. Governments could introduce "carrot and stick" approaches, where companies that voluntarily comply with stricter noise reduction standards receive financial benefits—such as tax breaks, expedited permits, or access to new markets—while those that fail to comply face penalties, fines, or public reputational damage.

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[59] Vandenbergh, Michael P., Light, Scott S., & Salzman, James, Private Environmental Governance (Concepts and Insights Series) 53-61 (October 2023).
[60] Wysocki, L.E., Dittami, J.P., & Ladich, F., Ship Noise and Cortisol Secretion in European Freshwater Fishes, 128 Biol. Conserv. 501 (2006), https://doi.org/10.1016/j.biocon.2005.10.020
[61] Fairfax, Lisa M., Making the Corporation Safe for Shareholder Democracy, 69 Ohio St. L.J. 53 (2008

v. Industry Certifications and Consumer Engagement

Moreover, industry-specific certifications could be established to signal responsible practices to consumers. For instance, a shipping company that adheres to strict noise reduction standards could market itself as "cetacean-friendly" or "marine conservation certified." Such labels[62] would appeal to environmentally-conscious consumers and investors, creating financial incentives for businesses to act responsibly. Over time, these certifications could become the norm in the industry, fostering a culture of environmental stewardship across the global maritime sector.

vi. Collaboration with Environmental NGOs

Private actors can also collaborate with environmental NGOs to develop best practice guidelines and noise reduction technologies. This partnership between the private sector and civil society organizations would ensure that the solutions developed are scientifically sound and tailored to the specific needs of marine ecosystems. Furthermore, NGOs could provide independent oversight, helping to ensure that companies are held accountable for their noise reduction commitments.[63]

vii. Global Equity Implications of Private Governance

The global equity implications of marine conservation are also critical when considering private governance as a policy tool. Many developing countries, particularly in the Global South, lack the financial and technical resources to implement comprehensive environmental regulations.[64] However, private governance allows for the pooling of resources and expertise, enabling these countries to benefit from advances in technology and knowledge transfer from more developed nations. For example, international shipping companies operating in both the United States and Pakistan could introduce noise reduction measures in Pakistan as part of their global sustainability commitments, even if local regulations are insufficient.

viii. Private Governance as a Solution in Regions with Weak State Capacity

In regions where state capacity is weak, private governance initiatives can act as a powerful tool for filling regulatory gaps. By establishing industry norms that transcend national borders, private actors can help to create a level playing field that ensures cetacean conservation efforts are globally consistent, rather than fragmented by jurisdictional boundaries.

ix. Future of Hybrid Governance Models

Looking forward, I believe that the integration of private governance into marine conservation strategies could drastically improve cetacean protection efforts. As bioacoustic monitoring

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[62] Michael P. Vandenbergh, Private Environmental Governance, 99 Cornell L. Rev. 129 (2013) Available at: http://scholarship.law.cornell.edu/clr/vol99/iss1/3

[63] Vandenbergh, Michael P., Light, Scott S., & Salzman, James, Private Environmental Governance (Concepts and Insights Series) pg 231 (October 2023).

[64] Fairfax, Lisa M., Making the Corporation Safe for Shareholder Democracy, 69 Ohio St. L.J. 53 (2008)

becomes more advanced and industries become more aware of the economic and reputational benefits of environmental responsibility, we could see a shift toward a hybrid governance model, where the state plays a regulatory oversight role while the private sector leads in implementation and innovation.

x. Importance of Public Engagement and Awareness

In addition to the regulatory and technological advancements discussed, public engagement and awareness campaigns will be key to the success of these initiatives. By fostering a broader public understanding of the impacts of underwater noise on cetaceans, and the role of private governance in mitigating these impacts, consumers and stakeholders can drive market demand for sustainable practices. This will create an ecosystem where private actors are not only compliant with legal frameworks but are also driven by a broader societal commitment to marine conservation and sustainable development.

An Integrated Conservation Strategy for Pakistan

For Pakistan, adopting an integrated approach to marine conservation, specifically targeting underwater noise pollution, is essential. This strategy must prioritize the safeguarding of marine biodiversity and the ecological health of marine ecosystems, ensuring the protection of key species such as cetaceans. However, it is crucial that conservation efforts are tailored to the specific environmental, economic, and social conditions of Pakistan's coastal regions. The strategy must address the complex dynamics of Pakistan's marine environment, considering both local and global pressures, including the impact of industrial activities, overfishing, and climate change, alongside the need for sustainable livelihoods for coastal communities. An effective conservation plan will blend scientific research with local knowledge, engaging stakeholders at all levels to create a framework that balances ecological preservation with socio-economic needs, ensuring a sustainable future for both the marine ecosystem and the communities that depend on it.[65]

At the core of this approach is the reduction of underwater noise pollution, which poses a significant threat to marine life. Noise from shipping, industrial activities, and military operations disrupts cetaceans' communication, navigation, and hunting behaviors, leading to negative impacts on their survival. In addition to these direct impacts, noise pollution complicates existing conservation efforts, making it harder for marine species to thrive. Pakistan's conservation strategy should focus on monitoring and reducing noise levels in key habitats, as well as promoting technologies that minimize environmental noise. [66]

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[65] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf

[66] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf

By incorporating bioacoustic methods such as passive and active acoustic monitoring, Pakistan can better understand the extent of noise pollution and its effects on cetacean populations. Monitoring efforts should be integrated into marine conservation policies, ensuring that noise reduction measures are based on scientific data and aligned with international best practices. Through collaboration with international bodies and private sector partners, Pakistan can implement technologies and strategies that effectively address underwater noise pollution, contributing to a healthier marine environment.[67]

Conclusion: Advancing Marine Conservation Through Bioacoustics, Noise Pollution Management, and Private Governance

The health of global marine ecosystems is essential for maintaining biodiversity and ecological balance. These ecosystems face growing threats from industrial activities, particularly underwater noise pollution, which disrupts marine life, especially cetaceans. The impact of noise on marine species—altering behavior, communication, and reproductive success—has become a critical concern that requires immediate and comprehensive action. Addressing these challenges effectively demands an integrated approach that combines robust regulatory frameworks, the latest bioacoustic monitoring technologies, and the active involvement of private governance.

Cetacean conservation is directly linked to the management of underwater noise pollution. Marine mammals, including cetaceans, rely heavily on sound for communication, navigation, and hunting. Disruptions to these vital functions due to noise—whether from shipping, military operations, or industrial activities—can have profound consequences for their well-being. Integrating bioacoustic techniques, such as passive and active acoustic monitoring, is essential to understanding and mitigating these impacts. By accurately measuring noise levels and assessing their effects on cetacean behavior, policymakers can develop more informed and effective conservation strategies.

To build a sustainable future for marine ecosystems globally, it is essential to enhance international legal frameworks aimed at mitigating underwater noise pollution. While instruments like the United Nations Convention on the Law of the Sea (UNCLOS) provide a foundation for addressing marine pollution, enforcement remains a significant challenge, especially in international waters. The global nature of marine environments necessitates cooperation among nations to address cross-border pollution and adopt best practices for noise reduction. Drawing lessons from countries with more established frameworks, such as the United States and European Union members, offers valuable insights that can be tailored to different socio-economic and environmental contexts.

In addition to public sector regulation, private governance plays a crucial role in mitigating the impact of underwater noise pollution. Industries responsible for activities that contribute to marine noise—such as shipping, energy production, and military operations—must take an

[67] Merchant, N.D. (2018) Underwater noise abatement: Economic factors and Policy Options, Environmental Science & Policy. Available at: https://www.sciencedirect.com/science/article/pii/S1462901118310748

active role in reducing their environmental footprint.[68] By adopting quieter technologies, improving operational practices, and engaging in self-regulation, private companies can significantly contribute to the reduction of underwater noise. Moreover, private sector participation in marine conservation initiatives can complement government efforts, enabling more comprehensive and effective solutions.[69] Collaborative partnerships between governments, the scientific community, environmental organizations, and private industries can create a more sustainable and resilient marine conservation framework.

Ultimately, achieving meaningful progress in reducing underwater noise pollution requires action across all sectors. Governments must enforce marine protection laws more rigorously, especially those targeting noise pollution. The private sector must embrace corporate social responsibility, committing to practices that minimize environmental harm. The integration of bioacoustic monitoring technologies into policymaking, along with the active involvement of private governance, can create a more informed, accountable, and responsive approach to marine conservation.

In conclusion, protecting marine ecosystems and the species they harbor, particularly cetaceans, hinges on effective management of underwater noise pollution. By incorporating bioacoustic data into regulatory frameworks, strengthening international cooperation, and fostering private sector engagement, the global community can better address the impacts of noise on marine life. Through collective action, encompassing both public and private efforts, we can ensure a sustainable future where marine biodiversity thrives, and the health of marine ecosystems is safeguarded for generations to come.

[68] Erbe, C. & Farmer, D.M., Masked Hearing Thresholds of a Beluga Whale (Delphinapterus leucas) in Icebreaker Noise, 45 Deep Sea Res. II Top. Stud. Oceanogr. 1373 (1998).
[69] Fisheries:potential in Pakistan. Available at: https://tdap.gov.pk/wp-content/uploads/2022/03/Fisheries-Potential-of-Pakistan-Salma-Nusrat.pdf