Underwater Radiated Noise (URN) Management Technological and Policy Interventions

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Abstract: This research note delves into the multifaceted realm of underwater radiated noise management, focusing on the synergistic interplay between technological innovations and policy interventions, as well as the critical importance of acoustic capacity and capability building. Acoustic capacity building, encompassing "See, Understand, and Share" capabilities, forms the basis for comprehensive URN management strategies. The technological interventions categorized into sub-sections indicating their purposes in URN management such as noise Reduction, real-time monitoring, marine spatial planning, building SRP models, stakeholders' engagement and habitat restoration. Marine spatial planning (MSP) serves as a technological intervention by employing advanced software tools and data analysis techniques to manage human activities in marine environments. The International Maritime Organization (IMO) guidelines which aims to provide a comprehensive framework for reducing URN from ships. It targets various aspects of ship design, operation, and research & development. Moving forward, it is important to research how to adapt western techniques to IOR, emphasize the need for interventions in freshwater systems, to standardize and strengthen implications and make plans to regularly assess the impact of interventions and create awareness or motivation among stakeholders. This would certainly build the entire framework for URN management.

Keywords: *Underwater radiated noise, Acoustic capacity building, Marine spatial planning, Technological interventions, Policy interventions, SDGs, IMO guidelines.*

Introduction

Underwater Radiated Noise (URN) emerges as a critical environmental concern globally, impacting marine ecosystems and species dependent on underwater acoustic environments. The sources of underwater radiated noise are numerous and varied. Commercial shipping, for example, generates low-frequency noise from vessel engines, propellers, and hull interactions. Offshore oil and gas exploration and production activities produce noise from drilling operations, seismic surveys, and the deployment of underwater equipment. Military activities, including sonar operations and vessel movements, also contribute to underwater noise pollution.

The applications of understanding and managing underwater radiated noise are manifold, spanning environmental conservation, scientific research, offshore energy development, maritime transportation, and military operations. From assessing acoustic habitat degradation to enhancing acoustic stealth capabilities, the implications of noise management extend across diverse sectors. These efforts shape policy agendas and drive technological innovations aimed at mitigating the impact of underwater radiated noise on marine ecosystems.

Technological interventions such as acoustic monitoring systems and noise reduction technologies provide the data necessary for evidence-based policy formulation in URN management. Policies, in turn, guide the implementation and adoption of these technologies, ensuring regulatory compliance and effective mitigation of underwater radiated noise. This interaction fosters a balanced approach that supports sustainable marine conservation and ecosystem resilience in the face of anthropogenic noise impacts.

Acoustic capacity and capability building

Underwater Radiated Noise (URN) management and Acoustic Capacity Building are pivotal for sustainable marine conservation and effective governance, especially in regions like the Indian Ocean, which serves as a critical hub for global maritime trade, biodiversity hotspots, and vulnerable marine ecosystems. Acoustic capacity building, encompassing the development of "See, Understand, and Share" capabilities, is essential for robust URN management strategies.

Firstly, enhancing "See" capabilities involves deploying advanced sensors and acoustic monitoring networks. These technologies enable real-time data collection on URN sources and levels, crucial for monitoring and ensuring regulatory compliance. Improved sensor technologies also enhance the accuracy and coverage of monitoring efforts, providing a comprehensive understanding of noise impacts across diverse marine habitats.

Secondly, the "Understand" component of acoustic capacity building focuses on employing advanced analytics and modeling techniques. These tools interpret data trends, assess noise impacts on marine life, and forecast future scenarios. Such insights are vital for formulating targeted mitigation measures and adapting management strategies to evolving environmental conditions and human activities.

Lastly, the "Share" aspect emphasizes collaborative efforts among stakeholders within and beyond the Indian Ocean region. This involves sharing data, best practices, and technological innovations internationally. By fostering collaboration and harmonizing URN management policies across borders, stakeholders can collectively address global challenges posed by underwater noise pollution. [21]

Technological interventions

Technological interventions play a pivotal role in underwater radiated noise (URN) management, offering innovative solutions to mitigate the adverse impacts of anthropogenic noise pollution on aquatic environments. The importance of technological interventions in URN management stems from their ability to address various aspects of noise generation, propagation, and mitigation, thereby enhancing our capacity to safeguard the ecological integrity of oceans and freshwater systems. The technological interventions categorised into sub-sections indicating their purposes in URN management and are listed.

1. Building Source – Path – Receiver model

Source Identification and Characterization:

- Sources: Identify all significant sources of underwater radiated noise. This includes shipping traffic, naval activities, offshore drilling, seismic surveys, underwater construction, and marine renewable energy projects.
- Characterization: It is a challenging task to quantify noise emissions from each source in terms of frequency spectrum, intensity levels, temporal patterns, and duration of emissions. Quantification of impacts in URN management is essential and a challenging task

Path Analysis:

- Propagation Paths: Understand how noise propagates through the ocean:
    - Direct Paths: Noise travels directly from sources to potential receivers.
    - Reflected Paths: Consider how noise reflects off the sea surface, seabed, and other underwater structures.
    - Channel Effects: Evaluate how environmental factors such as water depth, temperature, salinity, and seabed composition influence noise propagation.
- Modelling: creating advanced acoustic modelling tools to simulate noise propagation paths and predict noise levels at different distances and depths from the source.

Receiver Sensitivity and Impact Assessment:

- Sensitivity: Identify sensitive receivers in the Indian Ocean, including marine mammals, fish, turtles, and other marine species vulnerable to noise pollution.
- Impact Assessment: Assess potential impacts of noise on marine life, considering thresholds for behavioural changes, stress, hearing damage, and interference with communication and navigation.

2. Real-Time monitoring

Real-time monitoring in underwater radiated noise (URN) management aims to track and mitigate noise emissions in real-time to minimize their impact on marine environments.

- Underwater Acoustic Sensors:
    - Deploy underwater acoustic sensors strategically in key locations to continuously monitor noise levels in real-time.
    - Sensors can be stationary or mobile (e.g., attached to buoys or autonomous underwater vehicles) to cover different depths and areas of interest.
- Data Transmission and Communication:
    - Utilize underwater communication technologies such as acoustic modems or satellite communication for real-time data transmission from sensors to monitoring stations.
    - Ensure data integrity and reliability to promptly assess noise levels and respond to changes or anomalies.
- Automated Alert Systems:
    - Implement automated alert systems triggered by predefined noise thresholds or unusual noise patterns.

    - Alerts can notify relevant stakeholders (e.g., regulatory authorities, vessel operators) immediately to take corrective actions or investigate potential sources of excessive noise.
- Monitoring of Anthropogenic Activities:
    - Focus real-time monitoring efforts on anthropogenic activities known to produce significant underwater noise, such as shipping routes, naval exercises, offshore drilling, and construction activities.
    - Monitor these activities continuously to ensure compliance with noise regulations and standards.[12][1]

Challenges: Real-time monitoring in Underwater Radiated Noise (URN) management faces several challenges. Technologically, developing robust sensors that can withstand harsh underwater conditions while ensuring reliable data transmission is complex. Spatially, achieving comprehensive coverage across vast oceanic areas requires strategic deployment of sensors, which is costly and resource intensive. Identifying and distinguishing noise sources in real-time poses difficulty, demanding advanced signal processing techniques. Integrating data from multiple sensors and aligning it with regulatory frameworks also presents challenges. Overcoming these obstacles necessitates continuous technological advancements, collaborative research efforts, and cohesive policy frameworks to effectively manage URN and safeguard marine ecosystems.

3. Marine spatial planning (MSP)

Marine spatial planning (MSP) is a systematic process of organizing human activities in marine areas to achieve ecological, economic, and social objectives. It involves analyzing and allocating spatial and temporal distribution of activities and resources in marine environments while considering environmental sustainability and stakeholder interests.

MSP integrates ecological, economic, and social factors to support sustainable development, conservation of marine biodiversity, and effective governance of marine resources. Key components include stakeholder engagement, data collection and analysis, mapping of marine uses and resources, identifying areas for specific uses (e.g., conservation, fishing, shipping), and establishing policies and regulations to guide decision-making and conflict resolution in ocean management. Here’s how MSP can be applied specifically for URN management:

Mapping Noise Sources and Sensitive Areas:

- Identifying Noise Sources: MSP involves mapping out the locations and intensities of major noise sources in marine environments, such as shipping lanes, naval exercises, offshore construction sites, and renewable energy installations.

- Identifying Sensitive Areas: MSP identifies and maps ecologically sensitive areas where marine organisms, especially marine mammals and fish, are vulnerable to the impacts of underwater noise.

Zoning and Spatial Allocation:

- Noise Mitigation Zones: MSP establishes noise mitigation zones or corridors where strict noise emission standards or regulations are enforced to minimize the impact of noise on sensitive species and habitats.
- Designated Areas for Quietude: MSP designates areas where noise-generating activities are restricted or regulated to maintain natural soundscapes and minimize disturbance to marine life.

Monitoring and Adaptive Management:

- Data-Driven Decision Making: MSP utilizes data from real-time monitoring systems (e.g., acoustic sensors) to assess noise levels, evaluate the effectiveness of mitigation measures, and adapt management strategies as needed.
- Feedback Loops: MSP incorporates feedback loops to adjust spatial plans based on new scientific information, changing environmental conditions, or stakeholder feedback regarding noise impacts.

Policy and Regulation Frameworks:

- Legal Frameworks: MSP establishes legal and regulatory frameworks that enforce noise emission standards, permit requirements, and mitigation measures for activities contributing to underwater noise.
- International Collaboration: MSP fosters collaboration among countries and regions to harmonize noise management practices, especially in transboundary marine areas like the Indian Ocean.[22][23]

4. Noise reduction technologies

Noise reduction technologies for underwater radiated noise (URN) management are crucial for minimizing the impact of human activities on marine environments. Here are several key technologies and strategies specifically designed to reduce underwater noise emissions:

Propulsion System Improvements:

- Advanced Propeller and Hull Designs: Develop propellers and hull designs that minimize cavitation and hydrodynamic noise, which are major sources of noise from ships and vessels.
- Propeller Tip Modifications: Implement modifications to propeller tips to reduce vortex-induced vibrations and noise generation.
- Electric and Hybrid Propulsion: Electric and hybrid propulsion systems produce less noise compared to traditional diesel engines, especially at lower speeds and during manoeuvring.[19]

Noise-Reducing Equipment and Devices:

- Mufflers and Silencers: Install underwater mufflers and silencers on propulsion systems, pumps, thrusters, and other equipment to dampen noise emissions.
- Acoustic Insulation: Use sound-absorbing materials and coatings on hulls, equipment housings, and underwater structures to reduce noise propagation.
- Vibration Isolation: Implement vibration isolation techniques to reduce mechanical vibrations that contribute to underwater noise.[19]

Operational and Behavioural Adjustments:

- Route Optimization: Use acoustic modelling and real-time monitoring data to optimize vessel routes, avoiding areas with high concentrations of marine life or sensitive habitats.[19]

Active and Passive Noise Mitigation:

- Active Noise Cancellation: Employ active noise control technologies that emit anti-noise waves to cancel out specific frequencies of noise emitted by machinery and equipment.[1]
- Passive Noise Reduction: Utilize passive measures such as acoustic barriers, curtains, or shields to reduce noise propagation into the surrounding water column. [9]
- Underwater Noise Blankets: Deploy noise-absorbing blankets or barriers around noisy operations to mitigate noise emissions directly at the source.[1]

Challenges: Implementing noise reduction solutions for underwater radiated noise (URN) management poses several practical challenges:

1. Cost and Investment: Many noise reduction technologies involve significant upfront costs for research, development, and implementation. Retrofitting existing vessels or structures with noise-reducing equipment like mufflers, silencers, or acoustic insulation can be expensive. This financial barrier may deter widespread adoption, especially for smaller operators or in developing regions.

2. Engineering Complexity: Designing and implementing effective noise reduction solutions often requires specialized engineering expertise. Advanced propeller designs, propeller tip modifications, and acoustic insulation materials must be tailored to specific vessels and operational environments. Achieving optimal noise reduction while maintaining vessel performance can be technically challenging.

3. Operational Impact: Introducing noise reduction technologies and practices can impact vessel operations and performance. Changes in propulsion systems (e.g., switching to electric or hybrid propulsion) or adding acoustic insulation may alter vessel weight, balance, and fuel efficiency. Operators must carefully balance noise reduction goals with operational requirements to avoid unintended consequences.

4. Maintenance and Durability: Equipment used for noise reduction, such as mufflers, silencers, and acoustic materials, must withstand harsh marine conditions including corrosion, biofouling, and mechanical wear. Regular maintenance and replacement of these components are essential to ensure continued effectiveness, which can be logistically challenging in remote or offshore locations.

5. Regulatory Compliance: Implementing noise reduction solutions must align with international, national, and local regulations governing maritime activities. Compliance requirements may vary widely across jurisdictions, necessitating careful navigation of regulatory frameworks to ensure adherence while implementing effective noise mitigation measures.

6. Stakeholders engagement

Technological advancements offer a powerful toolbox for improved stakeholder management in URN management. Digital platforms like online forums, webinars, and interactive maps foster discussions and data visualization, enabling transparent information sharing and collaborative problem-solving. Real-time monitoring empowers stakeholders with dashboards and alerts on noise levels and regulatory updates, keeping everyone informed and engaged. Mobile applications further enhance participation by allowing users to report incidents and contribute to citizen science initiatives. Finally, social media and online campaigns leverage the power of online communities to raise awareness, conduct targeted outreach, and gather valuable data through crowdsourcing initiatives. This multifaceted approach ensures all stakeholders have a voice and feel invested in the success of URN management efforts.[24][25]

7. Habitat restoration

Deploying artificial reefs involves more than simply dumping concrete blocks. These structures, crafted from diverse materials such as sunken ships or specially designed modules, serve to create intricate habitats that attract a broad array of marine species. However, their significance extends beyond mere attraction; incorporating noise-reducing materials into these reefs establishes quieter sanctuaries for marine life. Moreover, bioacoustics devices enhance these environments by emitting sounds that attract specific creatures, facilitating colonization and fostering robust connections within the ecosystem. Even traditional underwater structures like fish aggregating devices can be redesigned with noise mitigation strategies, ensuring that restoration efforts minimize disturbance to marine biodiversity. [11-17]

Policy interventions

Policy interventions are vital for managing underwater radiated noise pollution. The costs of noise pollution are not directly borne by those responsible, such as shipping companies. Without regulations incentivizing investment in quieter technologies or operational practices, polluters lack the motivation to mitigate noise emissions. Lack of public awareness, and international cooperation also underscore the need for regulations. Scientific evidence highlights the urgent need for action, despite challenges in quantifying ecological costs. Policies incentivize mitigation measures, raise awareness, and foster international collaboration. SDGs play a crucial role in promoting environmental awareness, providing a framework for policy development, and monitoring progress towards a healthier ocean. They can indirectly influence governments and international organizations to implement policies that address underwater noise pollution.

Detailed Note on IMO Guidelines: Revised MEPC.1/Circ.906

Underwater radiated noise (URN) from commercial shipping poses a significant threat to marine life. To address this growing concern, the International Maritime Organization (IMO) released revised guidelines, MEPC.1/Circ.906, which supersede the previous MEPC.1/Circ.833. This note delves into the details of MEPC.1/Circ.906, highlighting its key aspects and objectives. MEPC.1/Circ.906 aims to provide a comprehensive framework for reducing URN from ships. It targets various aspects of ship design, operation, and research & development. Here's a breakdown of the key areas addressed:

Quieter Propeller Designs: The guidelines encourage the adoption of propeller designs that generate less noise, such as contra-rotating propellers or wake-equalizing ducts.

Hull Optimization: Strategies to minimize cavitation noise are emphasized. This includes optimizing hull shapes to reduce the formation and collapse of air bubbles around the propeller.

Noise Insulation: The guidelines recommend incorporating noise insulation materials into engine compartments and other noise-generating machinery spaces.

Operational Measures: Slow Steaming: Encouraging the practice of reducing ship speed in sensitive marine areas to lessen URN generation.

Alternative Propulsion Methods: Promoting the use of electric or wind propulsion systems during specific activities, particularly in noise-sensitive zones.

Sonar Usage: Guidelines advocate for the responsible use of sonars, minimizing unnecessary transmissions and exploring quieter sonar technologies.

Quieter Technologies: The IMO encourages continued research and development of quieter ship designs, propellers, and alternative propulsion systems.

Noise Measurement Techniques: Developing more accurate and standardized methods for measuring underwater radiated noise from ships is crucial for effective monitoring and enforcement.

Impact Assessments: The guidelines emphasize the need for research on the impact of URN on various marine species to inform future noise management strategies. [18]

Key Improvements over MEPC.1/Circ.833:

MEPC.1/Circ.906 builds upon the previous guidelines by offering a more comprehensive and updated framework. The revised guidelines place greater emphasis on ongoing research to develop quieter technologies and improve noise measurement techniques. More specific recommendations are provided regarding slow steaming practices and the use of alternative propulsion methods. The guidelines acknowledge the need for better data on the impact of URN on different marine species, paving the way for more targeted mitigation strategies.

Challenges and Considerations:

While MEPC.1/Circ.906 represents a significant step forward, some challenges remain. The guidelines are currently not mandatory, relying on individual countries for implementation. The lack of robust enforcement mechanisms for these guidelines presents a hurdle in ensuring widespread adoption. The development and implementation of quieter technologies require ongoing research, investment, and collaboration within the maritime industry.

Effective management of underwater radiated noise from maritime and offshore activities requires a strategic approach encompassing several policy options. Firstly, prioritizing ship-quieting technologies at the design stage of new vessels emerges as crucial, as retrofitting existing ships proves less effective and more costly (Spence and Fischer, 2017). Secondly, implementing mandatory noise standards for new vessels, scaled according to their transport capacity akin to aviation standards, presents a direct method to mitigate noise emissions (Smith, 2004). This approach not only encourages quieter vessel designs but also promotes the use of larger, less noisy vessels. Thirdly, addressing the challenge of existing vessels involves establishing international standards for measuring ship noise emissions under realistic operational conditions, supported by comprehensive monitoring along major shipping routes (ISO, 2016; McKenna et al., 2013). These efforts could be facilitated through coordination by international bodies such as Regional Seas Conventions (OSPAR, Cartagena Convention). Incentive-based measures, such as reduced port fees for quieter vessels under programs like the Port of Vancouver's ECHO initiative, offer additional encouragement for ship owners to adopt noise-reducing technologies voluntarily. Lastly, for activities like seismic airgun surveys that significantly contribute to underwater noise pollution, policies promoting the development and adoption of quieter technologies through progressive levies and regulatory standards could be pivotal (Andresen, 2017; BOEM, 2017). These measures align with broader environmental goals, ensuring sustainable marine ecosystems amidst ongoing maritime and offshore operations.[19]

On 11 March 2024, the European Commission introduced binding limits to combat underwater noise pollution across the EU, marking a significant advancement in marine conservation. Mandated under the Marine Strategy Framework Directive (MSFD), these measures require Member States to integrate noise thresholds into their marine strategies by October 2024. Supported by the International Fund for Animal Welfare (IFAW), these regulations aim to achieve Good Environmental Status (GES) for marine waters. Operational measures, such as the Blue Speeds campaign advocating speed reductions for commercial vessels, promise immediate reductions in noise pollution and environmental impacts from shipping. The European Union have begun adopting their own regulations for underwater noise within their territorial waters. This trend may influence future developments in the Indian Ocean region. [20]

Conclusion

In conclusion, effective management of Underwater Radiated Noise (URN) in the Indian Ocean Region (IOR) requires a comprehensive approach that integrates technological advancements and robust policy interventions tailored to the region's unique ecological and socio-economic contexts. This includes extending interventions beyond marine environments to encompass freshwater systems, recognizing their interconnectedness and shared susceptibility to URN impacts. Enhancing acoustic monitoring systems, underwater sensors, and noise reduction technologies specifically suited to tropical conditions prevalent in the IOR is crucial.

Standardizing regulatory frameworks across IOR nations and implementing regular impact assessments are essential steps toward ensuring consistent and effective URN management practices. Moreover, fostering stakeholder engagement and raising awareness are integral to achieving compliance and garnering support for URN mitigation efforts. By harmonizing technological innovation with sound policy implementation, the IOR can establish a cohesive framework that promotes sustainable marine conservation and enhances ecosystem resilience. This integrated approach will play a vital role in safeguarding marine biodiversity and ensuring the long-term health of ocean ecosystems amidst increasing anthropogenic noise challenges.

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