

Minimax-Based Assessment of Anthropogenic Underwater Noise and Its Behavioral Impacts on Marine Fauna: A Scientometric Analysis

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Abstract

Anthropogenic underwater noise, mainly from maritime traffic like shipping, is increasingly altering the ocean's acoustic environment, disrupting essential behaviors in marine mammals, fish, and invertebrates. This chronic noise pollution causes physiological stress, behavioral changes, habitat avoidance, and threatens marine populations and ecosystem resilience globally. Despite acknowledged impacts, knowledge gaps persist regarding cumulative and interactive effects of noise with other stressors (e.g., pollution, climate change), and varying regional and species sensitivities complicate risk assessments and mitigation. This study systematically reviews scientific research from 2001 to mid-2025 on maritime noise pollution's behavioral and physiological effects on marine fauna through global scientometric analysis of peer-reviewed literature. It identifies research trends, thematic focus, geographic distribution, technological advances, and gaps to guide future conservation and policy efforts. Findings show a recent surge in publications, with two main thematic clusters: broad animal noise pollution studies (including terrestrial) and focused marine mammal behavioral research. Research is concentrated in developed maritime nations like the USA, UK, Canada, and China, while biodiversity hotspots are underrepresented. Innovations such as passive acoustic monitoring and machine learning improve impact detection. Studies reveal species-specific responses, from stress in marine mammals to physiological harm in oysters. Proposed policies emphasize coordinated multi-level governance but face implementation challenges. Continued global collaboration, technology sharing, and integrated strategies are critical to effectively mitigate underwater noise pollution and protect marine biodiversity.

KEYWORDS: Anthropogenic impacts, marine fauna, marine mammals, scientometric analysis, underwater noise

Introduction

Human activities are increasingly reshaping the acoustic environment of the world's oceans, introducing persistent underwater noise that threatens marine ecosystems globally. Among these activities, maritime traffic—primarily shipping—has emerged as the principal source of underwater noise, fundamentally altering marine soundscapes and disrupting vital life functions such as communication, navigation, foraging, and predator avoidance in marine mammals, fish, and invertebrates (Davies et al., 2024). Evidence shows that even moderate vessel speed reductions can significantly lower ship noise, thereby reducing its harmful impact on marine life and pointing to the potential of practical mitigation measures (Rojano-Doñate et al., 2023). Beyond shipping, noise generated in industrial aquaculture has also been shown to disrupt fish behavior, weaken immune and antioxidant systems, and reduce growth in species such as largemouth bass (Hang et al., 2021).

Despite such insights, considerable challenges persist. In regions such as the Mediterranean, noise pollution from chronic and acute sources—including shipping, pile driving, and seismic air guns—has been found to disrupt communication, physiology, behavior, health, and even the survival of fish and invertebrates. These effects, while initially observed at the individual level, may escalate to affect entire populations and ecosystems, highlighting the

urgent need for improved data collection and management strategies to curb noise impacts (Di Franco et al., 2020). Similarly, there is a recognized demand for normative regulation and refined measurement techniques to address the ecological effects of shipping noise (Marco-Franco, 2022). In the Arctic, where marine mammals are highly sensitive to low noise levels, studies emphasize precautionary management and expanded research to mitigate risks from rising industrialization and shipping activity in the region (Halliday et al., 2020).

Parallel to these ecological concerns, technological advances have transformed the monitoring and assessment of underwater noise. The use of passive acoustic monitoring networks, autonomous underwater vehicles, and computational noise mapping has enabled high-resolution analyses of vessel noise, supporting the identification of acoustic hotspots and the testing of mitigation strategies (Alam et al., 2020). Complementing these innovations, accessible systems such as the CORMA platform—a real-time, low-cost underwater noise monitoring device—demonstrate the practicality of continuous acoustic data collection for marine ecosystem management and long-term noise assessment (Diviacco et al., 2021).

However, despite these advances, significant research gaps remain. Most studies remain region-specific, offering limited understanding of long-term and large-scale patterns of maritime noise pollution at a global level. Moreover, the insufficient integration of biological impact studies with technological monitoring approaches hinders efforts to link acoustic data with ecosystem-wide effects. Normative frameworks and cross-regional comparative analyses are also scarce, constraining the development of unified strategies for global noise mitigation.

Addressing these gaps, the present study seeks to: (1) investigate the structural features and thematic clusters of research on maritime noise; (2) assess research outputs and emerging trends shaping the field; (3) evaluate advances in technological and methodological approaches for monitoring and mitigation; (4) map the geographic distribution of studies and capacity-building initiatives to identify disparities and strengths; and (5) explore the policy and conservation implications necessary to translate scientific knowledge into effective management and regulatory frameworks.

Methodology

Study Design

A quantitative, descriptive scientometric analysis approach (López-Pernas et al., 2022) was adopted to map the scientific literature pertaining to maritime noise pollution's behavioral effects on marine fauna (Hendricks et al., 2025). This entailed bibliometric and content analyses focusing on publication outputs, author and institutional networks, and thematic trends.

Search Strategy and Data Filtering

Systematic keyword searches using Boolean operators (Alharbi & Stevenson, 2020) targeted titles, abstracts, and keywords with terms related to underwater noise sources (e.g., “ship noise,” “seismic noise”), affected taxa (e.g., “marine mammal,” “fish,” “cetacean”), and impact endpoints (e.g., “behavioral response,” “stress response”). Only English-language peer-reviewed articles, reviews, and conference proceedings were retained. Records unrelated to biological impacts or terrestrial contexts, and duplicates, were excluded (Ryan, 2023).

Data Extraction and Analysis

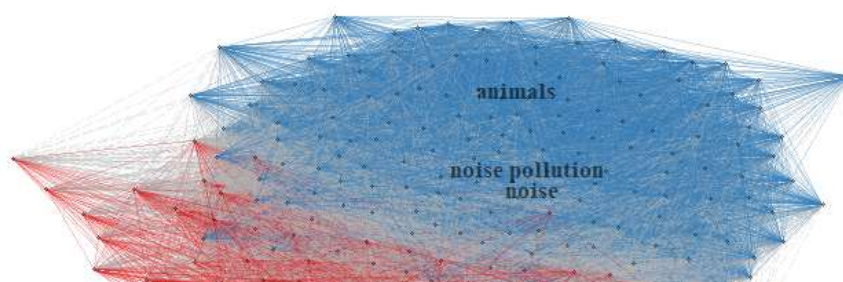
Bibliometric variables included yearly publication counts, citation frequencies, authorship, and journal distributions. Content variables captured study scope, geographic focus, taxa, noise types, methodological approaches, behavioral endpoints, and mitigation strategies. Keyword co-occurrence and topic modeling identified thematic clusters. Validation was performed by cross-referencing citations of seminal works. Data were organized using spreadsheets and bibliometric software for network visualizations and trend analyses.

Results

The results show different figures for data visualization for further analysis and discussion.

The interconnectedness of research themes by mapping frequently co-occurring keywords in maritime noise studies is illustrated in Figure 1. It highlights dominant concepts and their relationships, revealing the thematic structure of the field.

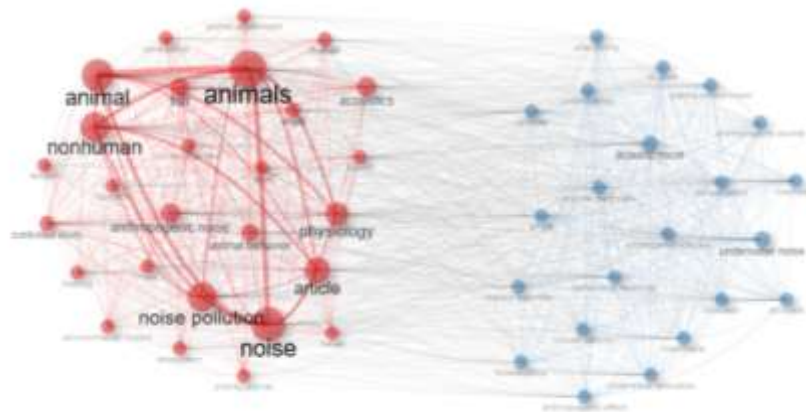
Figure 1. Keyword co-occurrences network



Source: Biblioshiny (2025).

The growth and distribution of research outputs over time is shown in Figure 2. It emphasizes emerging trends and shifts in scholarly focus on maritime noise and its ecological impacts.

Figure 2. Research Outputs and Trends



Source: Biblioshiny (2025).

The comparison on scientific contributions of different countries in maritime noise research is presented in Figure 3. It shows the nations leading in publication output and global knowledge production.

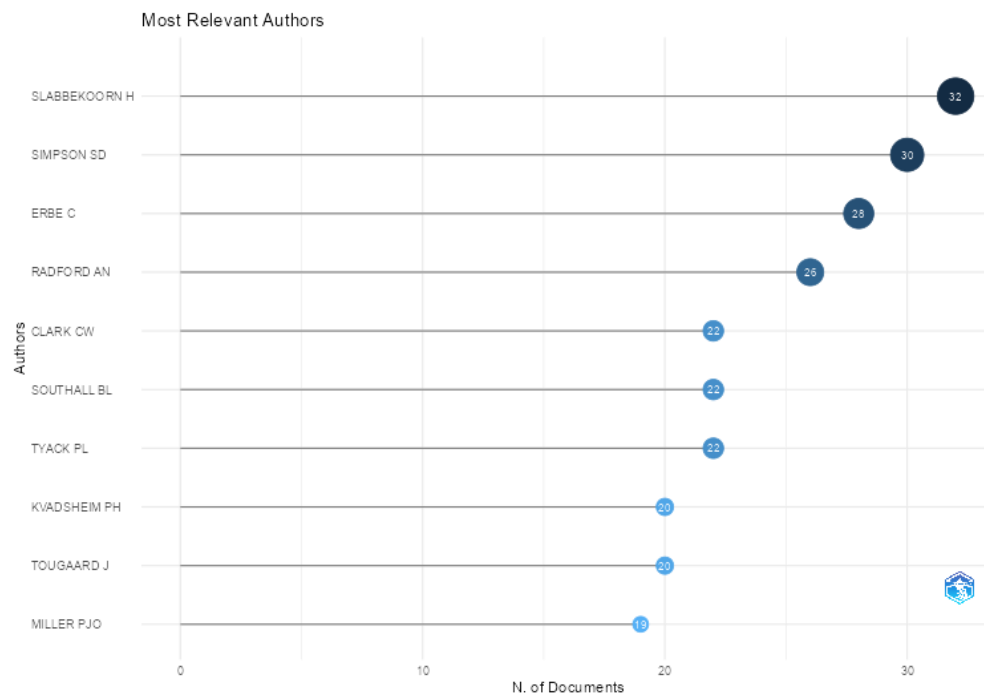
Figure 3. Country Scientific Production



Source: Biblioshiny (2025).

The most prolific authors in maritime noise research through a bubble chart is visualized in Figure 4. Bubble sizes indicate the relative publication output and influence of each author.

Figure 4. Bubble Chart of the Top 10 Most Relevant Authors



Source: Biblioshiny (2025).

Table 1 lists the countries with the highest number of publications on maritime noise and its impacts on marine fauna. The USA, UK, and Canada emerge as the most active contributors in this research domain.

Table 1. Top Ten Most Active Countries of Maritime Noise Pollution and Behavioral Disruption on Marine Fauna

Country	Number of Publications
USA	1,552
UK	717
Canada	556
China	493
Netherlands	290
Australia	279
Italy	251
France	184
Germany	161
Japan	127

Source: Own design (2025).

Table 2 summarizes the leading authors in maritime noise research, detailing their publication count, research focus, and regional influence. It also highlights their key contributions, ranging from policy development to species-specific behavioral studies.

Table 2. Top Ten Most Active Authors, Publication Focus Area, Region of Influence and Their Key Contributions to the Subject Area

Name of Author	Number of Publications	Focus Area	Region of Influence	Key Contribution
Slabbekoorn H	32	Fish behavior, EU policy, soundscapes	Europe	Acoustic communication; bird song adaptation to noise
Simpson SD	30	Coral reef ecology, larval orientation	Indo-Pacific, Caribbean	Marine acoustic ecology; anthropogenic noise impact
Erbe C	28	Noise modeling, marine mammals	Canada, Australia	Underwater acoustics; marine mammal noise exposure
Radford AN	26	Stress responses, small-scale experiments	UK, tropics	Animal communication; ecological effects of sound pollution
Clark CW	22	Whale conservation, seismic/sonar impacts	Global	Marine mammal communication; sonar impact
Southall BL	22	Hearing thresholds, regulatory standards	USA, international	Policy development; aquatic noise exposure guidelines
Tyack PL	22	Cetacean social behavior, sonar exposure	Atlantic, Mediterranean	Bioacoustics; behavioral effects of sonar on marine life
Kvadshem PH	20	Arctic noise, long-term monitoring	Germany, polar regions	Behavioral ecology; noise-induced behavioral changes
Tougaard J	20	Harbor porpoise behavior, wind energy	Denmark, North Sea	Noise monitoring; cetacean conservation
Miller PJO	19	Telemetry, deep-diving cetaceans	Scotland, polar seas	Acoustic tracking; sonar response in marine mammals

Source: Own design (2025).

DISCUSSION

Structural Features and Thematic Clusters

The keyword co-occurrence network analysis revealed two prominent, distinct thematic clusters. One cluster (blue) centers on broad “animals,” “noise pollution,” and general “noise” impacts, indicating a wide scope that includes terrestrial and other taxa beyond marine fauna. The other cluster (red) distinctly focuses on “underwater noise,” “whale,” and “behavioral response,” underscoring a specialized research emphasis on marine mammals and specific behavioral effects stemming from underwater anthropogenic noise (European Environment Agency, 2025). The special issue on marine noise pollution highlights recent advances in understanding the ecological impacts and mitigation strategies of underwater noise (Azarm-Karnagh et al., 2023). This bifurcation reflects the scholarly community’s increasing specialization, where general studies on noise pollution coexist alongside a deepening focus on marine ecosystems, especially on how underwater noise influences marine mammal communication, migration, and welfare (Erbe et al., 2019). The centrality and frequency of these keywords demonstrate their dominance as research focal points, suggesting that the field has matured into distinct but interrelated subdomains.

Research Outputs and Emerging Trends

There has been a substantial increase in research output over the last five years, highlighting growing scientific and policy interest in maritime noise pollution and its biological consequences. This uptick is reflected in dense bibliometric networks and supported by meta-analyses showing diversification of research themes (European Environment Agency, 2025). The recognition that underwater noise travels great distances, affecting essential animal

behaviors such as prey detection, predator avoidance, navigation, and social communication, fuels demand for sustainable management strategies at various administrative levels (Chahouri et al., 2022).

Prominently, research on underwater noise effects has gained momentum, largely propelled by concerns about shipping noise, seismic surveys for oil and gas exploration, and emerging offshore energy industries. The pronounced co-occurrence of “whale,” “underwater noise,” and “behavioral response” illustrates dedicated efforts to understand how these noise sources influence marine mammal populations, including communication disruption and migration pattern alterations (Erbe et al., 2019). Shipping activities generate continuous low-frequency noise affecting marine ecosystems, disrupting vital processes and potentially leading to population declines and community shifts, necessitating mitigation strategies and noise limits on new ships and existing vessels.

The natural soundscapes of lowland river habitats are threatened by urban noise pollution, focusing on its impact on migratory fish. While not bird-specific, this work broadens the acoustic ecology context to aquatic species, highlighting the cross-taxa significance of anthropogenic noise (Te Velde et al., 2024). Soundscape analysis of coral reef habitats reveals distinct ecological differences, with specific soundscape features closely linked to benthic composition and biological communities, including fish and invertebrate activity, especially at night (Azofeifa-Solano et al., 2025).

Significantly, chronic anthropogenic noise can disrupt animal communication, leading to altered behavior and physiology across wildlife communities and potentially reshaping ecosystem structure and function. The review underscores major gaps in our understanding—particularly at the community level—emphasizing the need for long-term studies to inform mitigation strategies for ecological sound pollution (Kok et al., 2023).

Bahtiarian (2022) highlights that underwater shipping noise has become a pervasive global pollutant, profoundly affecting marine life by disrupting communication, navigation, and feeding behaviors across diverse species. The study emphasizes the urgent need for international regulatory frameworks and technological innovations to mitigate ship-generated noise and safeguard marine ecosystems.

Apparently, the growing body of research on the effects of ship noise on marine mammals highlights that such noise causes behavioral changes, acoustic masking of communication and echolocation, and stress responses. It also points out significant knowledge gaps, including limited studies on deep-diving and pelagic species, challenges in accurately measuring noise exposure, and unknown biological significance of observed responses, emphasizing the need for standardized research methods to better assess chronic noise impacts globally (Erbe et al., 2019). Underwater noise from shipping activities causes ecological disturbances such as stress and behavioral changes in marine life, and emphasizes the importance of implementing mitigation strategies including improved ship design, operational measures, and international guidelines (Güney & Kınacı, 2024). The International Maritime Organization (IMO) has recognized these issues, issuing guidelines aimed at reducing underwater radiated noise (Spence, 2024).

Researchers have documented the physiological and behavioral effects of underwater noise on fish, showing how prolonged exposure can mask essential acoustic cues and disrupt vital behaviors, posing risks to fish populations in increasingly noisy oceans (Slabbekoorn et al., 2012).

Similarly, underwater noise in ports and harbors has increased significantly due to shipping and construction activities, posing potential effects on marine animals, but noise levels are often disconnected from human perception and vary by species and water depth (Nedwell & Brooker, 2023).

Beauchaud et al. (2024) demonstrate that anthropogenic boat noise alters the behavior of the coral reef fish *Dascyllus* emano by causing them to stay closer to coral refuges and reduce their foraging range, which weakens their predation strength and disrupts trophic interactions in coral reef ecosystems. Their study combines in situ observations and controlled experiments, revealing that noise-induced behavioral changes likely affect predator-prey dynamics and the overall ecological balance in coral reefs.

Species-specific biological impacts have been observed in controlled and field studies. For instance, Ledoux et al. (2023) demonstrated that Eastern oysters (*Crassostrea virginica*) displayed immediate behavioral responses—such as valve gape reduction—to simulated pile-driving noise but not to drilling or boating sounds. Notably, exposure to pile-driving noise also depleted energy reserves (glycogen) in oyster adductor muscles, signaling physiological stress. Similarly, anthropogenic underwater noise negatively affects the movement and feeding performance of the red cherry shrimp (*Neocaridina davidi*), by causing changes in spatial distribution, increased latency to find food, and reduced feeding success (Azarm-Karnagh et al., 2023).

Advances in Technological and Methodological Approaches

Emerging technological innovations are reshaping the capacity to monitor and understand marine noise impacts more accurately and cost-effectively. Gröger et al. (2025) presented the development of a novel non-invasive opto-acoustic underwater fish observatory in Kiel Bight, which enabled high-resolution, continuous monitoring of fish species composition and behavior without disturbing the marine environment. Stafford et al. (2020) evaluated strategies to address environmental breakdown, highlighting the importance of integrating renewable energy, efficiency, and nature-based solutions for effective climate mitigation and ecosystem restoration. Their analysis emphasizes that combining these approaches can optimize environmental outcomes while supporting social equity and sustainable development goals in the face of ongoing ecological challenges.

The paper *The underwater soundscape of the North Sea* presents a unique dataset of underwater noise levels collected at 19 sites across the North Sea from 2019 to 2020, covering multiple countries and providing a comprehensive baseline for future noise monitoring in the region (Basan et al., 2024). The study characterizes ambient noise by identifying clusters of similar sound characteristics across three broadband frequency bands, revealing correlations between noise levels and environmental factors such as wind speed, ship distance, and ocean current velocity, thereby emphasizing the importance of spatial variability in assessing and managing underwater noise impacts (Tougaard, 2023).

In addition, a study by Wensveen et al. (2019) demonstrates that northern bottlenose whales in a largely pristine environment exhibit strong behavioral reactions to naval sonar signals, both near and far, including disrupted feeding, avoidance movements, and deep diving to escape the noise. Their findings reveal that the whales respond at relatively low received sound levels, with avoidance behaviors occurring over distances up to 28 km, highlighting significant sensitivity to sonar disturbance even in areas with minimal prior exposure.

Specifically, hybrid systems combining optical and acoustic sensors hold particular promise. Gröger et al. (2025) developed a non-invasive Underwater Fish Observatory (UFO) that integrates high-resolution optical imaging with medium-to-far-field 2D imaging sonar, enabling continuous and automated ecosystem monitoring over diverse spatial scales. Their 86-day multiparametric dataset from the Kiel Bight revealed ecologically significant shifts in fish community dynamics, exemplifying new horizons for non-invasive, long-term biodiversity assessment.

It is crucial to point out that the **Polar Sounds project** creatively bridges science and art by enabling over 100 artists to reinterpret underwater sound recordings from the Arctic and Southern Oceans, transforming scientific acoustic data into diverse musical compositions that engage wider public audiences with ocean research (Whittaker et al., 2024). This innovative collaboration highlights the potential of sound as a sensory medium to enhance ocean understanding and raise awareness about marine environments within the framework of the United Nations Decade of Ocean Science for Sustainable Development. Quantitative analyses also confirm that high-frequency shifts confer communication benefits in noisy urban habitats, improving signal transmission and reception (Slabbekoorn et al., 2012). Moreover, the utilization of nighttime soundscapes and the **Soundscape Code** as effective tools for coral reef ecosystem monitoring and conservation planning has been suggested, providing new opportunities for biodiversity assessment and habitat management (Azofeifa-Solano et al., 2025).

Corollary to this, exposure to naval sonar disrupts the deep foraging dives and echolocation behavior of beaked whales, causing them to cease foraging and make unusually slow ascents, which can have fatal consequences such as stranding and decompression sickness (Tyack et al., 2016). These findings have informed risk criteria and regulatory frameworks aimed at reducing sonar's harmful impacts on marine mammals, emphasizing the need for environmentally sustainable sonar use policies (Tyack, 2025). Furthermore, acoustic tracking and tagging studies have demonstrated that exposure to naval sonar leads to avoidant behaviors and cessation of foraging in beaked and bottlenose whales, with dose-response relationships quantified using data from both fixed acoustic recorders and animal tags (von Benda-Beckmann et al., 2019). This body of research highlights the variability and challenges in accurately estimating the received acoustic dose, which has direct implications for developing effective marine mammal protection guidelines.

Moreover, Silveira et al. (2021) integrated remote sensing data from WorldView-3 and Landsat-8 with machine learning techniques to map suitable habitats for coral reef species in marine protected areas, demonstrating the potential of combining nurture (environmental factors) and nature (species traits) for effective reef habitat mapping. This approach enhances spatial resolution and classification accuracy, offering valuable insights for coral reef conservation and management.

Supporting further development in biodiversity monitoring are Robotic and Autonomous Systems (RAS), which are considered transformative tools for overcoming challenges related to site access, species detection, data handling, and power supply, particularly in remote or difficult environments. Pringle et al. (2023) emphasize the importance of interdisciplinary collaboration between biodiversity researchers and robotics engineers to co-develop advanced technologies tailored for comprehensive biodiversity assessment.

Another significant advancement is in the field of acoustic monitoring for whale conservation. Clark et al. (2023) emphasize the importance of advanced passive acoustic monitoring for the conservation of endangered species such as the North Atlantic right whale, underscoring the detrimental effects of anthropogenic noise and shipping on whale populations and overall ecosystem health. Their work at Cornell Lab's K. Lisa Yang Center for Conservation Bioacoustics integrates bioacoustic data with ecological and management strategies to mitigate threats from human activities in marine environments. Complementing these efforts, underwater noise monitoring initiatives, including contributions to the Joint Monitoring Program for Ambient Noise in the North Sea (JOMOPANS), have produced

validated soundscape maps that assess the dominance of shipping noise and support policy measures under the European Marine Strategy Framework Directive (EMSFD; Tougaard, 2023). Together, these approaches highlight the essential role of acoustic data in informing conservation practices and guiding sustainable management of marine soundscapes.

Geographic Distribution and Capacity Building

Research efforts on underwater noise and its impacts are largely concentrated in developed maritime nations, with the United States leading (1,552 publications), followed by the United Kingdom (717), Canada (556), and China (493). The United States, with key contributors such as Southall, Nowacek, Miller, and Tyack, dominates regulatory-related research on hearing thresholds and aquatic noise exposure standards, underscoring its role in shaping international policies (Southall et al., 2016). In addition, Southall et al. (2019) provide updated scientific noise exposure criteria for marine mammals, establishing frequency-weighted sound exposure levels that predict temporary and permanent hearing damage while emphasizing species-specific auditory sensitivities and the probabilistic nature of behavioral and auditory responses to noise. Meanwhile, the United Kingdom and Canada have focused extensively on coastal and Arctic marine mammal monitoring, addressing critical threats such as icebreaking noise impacts on narwhals in the Beaufort Sea and Baffin Bay (Halliday et al., 2020).

Conversely, biodiversity-rich but capacity-limited regions in Africa and the Pacific remain underrepresented in published research. Capacity-building initiatives, such as the International Quiet Ocean Experiment (IQOE) and programs by the Western Indian Ocean Marine Science Association (WIOMSA), are actively working to transfer acoustic monitoring knowledge and technology to these regions (Boyd et al., 2011). In addition, Winship and Jones (2023) reviewed the use of acoustic monitoring to enhance health and welfare assessments of professionally managed marine mammals, emphasizing the importance of evaluating their hearing and vocal behaviors as critical indicators. They propose integrating methods such as behavioral hearing tests, auditory evoked potentials, and passive acoustic monitoring systems like the Welfare Acoustic Monitoring System (WAMS) to detect anthropogenic noise impacts and vocal biomarkers of health, aiming to improve holistic welfare management in marine mammal care. Similarly, Miller, Johnson, Tyack, and Terray (2019) advanced the understanding of marine mammal responses to sonar through acoustic tracking and tagging methods, showing that sonar exposure can cause significant behavioral changes such as cessation of foraging and avoidance responses in species like beaked whales. Their work combines passive acoustic monitoring with detailed movement and behavioral data from tags to quantitatively assess dose-response relationships and inform sound exposure guidelines for marine mammal protection.

Supporting previous studies, Saba et al. (2025) examine the progress and ongoing challenges in building ocean science capacity in Africa, highlighting significant impacts such as improved regional research collaboration, enhanced training programs, and increased access to marine data. Despite these advances, their study emphasizes persistent obstacles, including limited funding, infrastructural deficits, and the need for stronger policy support to sustain and expand oceanographic research across the continent.

Policy and Conservation Implications

The growing body of research directly informs policy-making and conservation strategies, as evidenced by the frequent association of terms such as environmental impact in recent studies (European Environment Agency [EEA], 2025). A multidisciplinary policy framework has been proposed to address underwater noise from commercial vessels, emphasizing the need for coordinated legal, technical, and operational measures across international, national, and local levels to ensure effective mitigation (Vakili et al., 2020). This framework underscores the persistent gaps between theoretical mitigation strategies and their practical implementation, particularly in complex port environments. Complementing these efforts, the OPERA project (Ocean Prediction Enhancement in Regions of Africa) has emerged as a significant initiative aimed at strengthening ocean prediction capacities across Sub-Saharan Africa by establishing regional centers of excellence and developing fit-for-purpose forecasting systems and services. Funded by the European Union and coordinated by Mercator Ocean International, OPERA focuses on fostering cooperation, digital innovation, targeted training, and community building to support sustainable ocean management and the growth of the blue economy (Diarra et al., 2025).

Passive acoustic monitoring emerges as an essential tool not only for ecological assessment but also for enforcement and compliance verification of noise regulations. Ongoing advancements in acoustic sensor technologies, data processing, and integrative modeling promise to enhance decision-making capabilities.

Nevertheless, significant challenges remain. Research on noise pollution in the Mediterranean demonstrates that both chronic and acute noise from human activities such as shipping, pile driving, and air guns can cause substantial disruptions to fish and invertebrates, negatively affecting their communication, physiology, behavior, health, and survival. These individual-level effects have the potential to scale up, altering populations and entire ecosystems, which underscores the urgent need for improved data collection and management strategies to mitigate noise impacts in the region (Di Franco et al., 2020).

Furthermore, expanding monitoring into understudied regions and deploying scalable, cost-effective technologies will be critical to capturing global diversity and guiding sound management policies. Recent advances in systematic conservation planning (SCP) emphasize its role in cost-effectively achieving biodiversity conservation goals aligned with the Global Biodiversity Framework. These innovations include faster algorithms, integration of ecosystem services and multiple biodiversity facets, climate-smart strategies, and enhanced accessibility through online tools. At the same time, researchers recommend strengthening communication of planning uncertainty and building capacity to bridge the gap between science and practice (Giakoumi et al., 2025).

A study found that a large portion of valuable environmental data—up to 70%—is at risk of being lost or has already become inaccessible, resulting in an estimated \$105 million USD worth of data collection efforts effectively disappearing from science. The authors emphasize the importance of data rescue—identifying, preserving, and sharing vulnerable datasets—to maintain historical environmental records that are critical for understanding ecological changes and guiding future research and policy decisions (Bledsoe et al., 2022).

Conclusion

The scientometric analysis reveals a rapidly growing, increasingly specialized research landscape addressing the biological impacts of maritime noise pollution. Advances in monitoring technologies and methodologies, alongside geographic expansion of research capacity, are enabling improved understanding of species-specific responses and informing conservation policies. However, closing regional research gaps, refining cumulative impact assessments, and strengthening interdisciplinary approaches are essential steps forward. These efforts will underpin effective mitigation frameworks necessary to protect marine fauna and preserve ecosystem resilience in the face of escalating anthropogenic noise pressures.

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