URN management in freshwater systems
Emphasis on Ganges River dolphin

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Abstract: Underwater radiated noise in freshwater systems is a critical environmental issue affecting aquatic habitats globally. This research note examines the primary sources of underwater noise and their socio-economic implications, emphasizing spatial planning challenges. It focuses on river dolphins, notably the Ganga River dolphin *(Platanista gangetica)*, highlighting the adverse effects of noise pollution on this endangered species. The political, economic, environmental, and cultural significance of the Ganga River dolphin underscores the urgency of conservation efforts. The Indian government and international organizations have implemented policies and regulations to mitigate noise pollution and protect river dolphins. Future research should expand beyond dolphins to investigate how underwater noise affects a variety of freshwater species, including fish, invertebrates, amphibians, and reptiles, across different types of freshwater habitats. Understanding the role of natural habitats like forests and mangrove forests in mitigating underwater noise impacts is essential for informing conservation and restoration efforts in freshwater ecosystems. Developing spatial planning frameworks like Maritime Spatial Planning (MSP) and implementing tailored policy and regulatory measures are crucial steps to effectively manage underwater noise in inland waters and promote sustainable development while safeguarding freshwater biodiversity.

Keywords: *Underwater radiated noise management, freshwater systems, shallow water, river dolphins, Ganges River dolphin, India, spatial planning, endangered species*

Introduction:

Underwater radiated noise management in marine started getting attention in international and regional stages in the recent years. It is also important to focus on the freshwater or inland water systems. URN significantly impacts the health of freshwater organisms, including fish, amphibians, and invertebrates that rely on sound for essential life functions such as communication, navigation, and locating food. Anthropogenic noise can disrupt these behaviours, leading to physiological stress, altered migration patterns, and reduced reproductive success. This disturbance can ultimately disrupt food webs and ecosystem dynamics, jeopardizing the overall health and stability of freshwater habitats.

Many countries have made their future plans for development of inland transportation and infrastructure building.[18,19] Engine noise, propellers, and high-speed boats from inland transportation significantly contribute to underwater noise in freshwater systems, potentially harming aquatic life by disrupting communication, hindering feeding, and causing stress. Hence it becomes essential for nations to study and understand the problem of underwater radiated noise in freshwater systems to make a sustainable development. This research note aims to explore current knowledge, gaps, and challenges in URN management within freshwater environments with emphasis on the river dolphins. By synthesizing existing literature and identifying key research areas, this study seeks to inform policy makers, researchers, and stakeholders about effective strategies to mitigate URN and safeguard the ecological integrity of freshwater ecosystems. Ultimately, understanding and addressing URN in freshwater systems is essential for ensuring the resilience and long-term sustainability of these vital aquatic habitats.

Major sources

A significant contributor to URN is boat traffic. Engine noise, propellers, and cavitation (bubble formation and collapse near propellers) from motorized boats create substantial underwater racket. The impact worsens with larger vessels and busier waterways. [4,5]

Dredging and construction activities are another source of URN. The underwater machinery used for these projects, including pile driving, blasting, and sediment removal equipment, generates loud noise that can travel long distances.[6]

Hydropower generation also contributes to URN. The underwater turbines used in hydropower plants create noise that travels far in rivers, potentially disrupting fish behaviour and communication near dams.[7]

Sonar use, although less common in freshwater compared to marine environments, can introduce noise into the ecosystem. This is especially true for high-powered active sonar systems used for fish finding or research.[6]

Finally, recreational activities like jet skis and underwater scooters add to the URN problem, particularly in popular areas. The noise generated by these watercrafts can be disruptive for aquatic life, especially during breeding seasons. [4,5]

It's important to note that natural phenomena like wind, rain, waterfalls, and ice movement can also contribute to URN in freshwater systems, although to a lesser extent than human activities. Additionally, the specific impact of each noise source depends on its intensity (loudness) and duration (how long the noise lasts), as well as the frequency of the sound. Different animal species have varying sensitivities to specific sound frequencies. Understanding these factors is crucial for developing effective strategies to minimize noise pollution and protect the health of our freshwater resources. [4,5]

Socio-economic dimension

Managing underwater radiated noise (URN) in freshwater systems presents a complex socio-economic challenge. Striking a balance between economic activities that generate URN and protecting the environment is crucial. Activities like commercial fishing, transportation by waterways, and hydropower generation provide jobs, income, and essential services. However, the noise associated with these activities can have negative consequences. Excessive URN disrupts fish communication and behaviour, potentially leading to reduced fish stocks and impacting fisheries, a vital source of income and food security for many communities. Similarly, noise pollution can disrupt tourism and recreational activities like fishing and boating, impacting tourism income, another vital economic driver in many regions. Furthermore, URN can harm sensitive aquatic species, leading to biodiversity loss and affecting related industries like ecotourism. Even water treatment costs can rise due to disrupted zooplankton populations, a crucial part of the aquatic food chain. [20,21]

Effective URN management requires a multi-pronged approach that considers the socio-economic context. Targeted regulations can address specific noise sources while minimizing impacts on economic activities. Investing in quieter engine technology for boats and exploring alternative energy sources for hydropower are steps towards reducing noise generation. Additionally, providing financial support for adopting quieter technologies and fostering collaboration between stakeholders, including fishermen, tourism operators, and conservation groups, can lead to solutions that balance economic needs with environmental protection. Encouraging responsible practices like using quieter boat engines, avoiding sensitive areas during breeding seasons, and exploring alternative transportation routes where feasible are all crucial aspects of a sustainable approach.

The benefits of effective URN management are significant. Healthy fish populations ensure long-term economic benefits for fisheries and related businesses. A thriving ecosystem with reduced noise pollution attracts tourists, boosting the local economy. Reduced noise pollution also improves the overall quality of life for communities living near freshwater systems. [8,9,10,11]

Challenges

Limited Escape for Freshwater Animals: Unlike vast oceans, freshwater habitats like rivers and lakes are confined spaces. When URN pollution occurs, freshwater animals often have limited options to escape the noise source. Factors like river currents, obstacles, or spawning grounds can further restrict movement for some species, making them even more vulnerable to chronic noise exposure. This restricted movement compared to marine animals makes URN pollution a more significant threat to freshwater populations.[12]

Complexity of River Environments: Unlike oceans, rivers have variable depths, flow velocities, and bottom composition. This complexity can make it difficult to predict how sound propagates and design effective noise reduction strategies.[13]

Limited Research: Compared to marine environments, there's a gap in research on the impact of URN on freshwater ecosystems and the effectiveness of mitigation techniques in rivers.[12]

Data Collection Challenges: Deploying and maintaining monitoring equipment like hydrophones can be difficult due to strong currents, changing water levels, and potential damage from debris. [13]

Competing Interests: Freshwater resources are crucial for various uses like transportation, irrigation, and recreation. Balancing these needs with noise reduction can be challenging. [8-11]

Enforcement and Regulations: Implementing and enforcing regulations on noise levels or boat operation can be complex, especially across jurisdictions or with limited resources.[14]

Opportunities

Smaller Scale: Freshwater systems are more localized than oceans, allowing for targeted noise reduction strategies in specific areas. This can be more cost-effective and lead to quicker improvements.

Direct Stakeholder Engagement: Collaboration with local communities, fishermen, and tourism operators can lead to more effective and socially acceptable management strategies.

Technological Advancements: New developments in quieter engine technologies for boats and innovative monitoring equipment can offer solutions for URN management.

Collaboration and Knowledge Sharing: Collaboration between researchers and managers working on URN in both marine and freshwater systems can accelerate progress.

Public Awareness: Raising awareness about the impact of URN on freshwater life can garner public support for conservation efforts.

Feasibility of Visual Surveys: Unlike the deep ocean where sound reigns supreme, the shallower, clearer waters of some freshwater systems allow for the use of visual surveys. This can be a valuable tool for monitoring boat traffic, identifying noise sources, and assessing the impact of URN on animal behaviour in certain situations. [17]

Spatial planning

URN management in marine is strongly supported by Marine Spatial planning (MSP) framework. Likewise, URN management in freshwater systems need a strategic framework of spatial planning. Hence it is important to find some suggestive steps to adapt MSP in freshwater systems. Key steps include identifying and mapping noise sources, distinguishing between continuous industrial noise and intermittent boat traffic, and categorizing their impacts. Zoning strategies involve designating noise-sensitive zones like wildlife sanctuaries and fish spawning grounds, coupled with buffer zones that restrict noisy activities around these areas. Traffic management initiatives, such as speed limits and alternative routes, aim to mitigate noise impacts, while seasonal restrictions target critical breeding periods for sensitive species.

In terms of land use planning, promoting noise-absorbing features like riparian forests and wetlands can serve as natural buffers against noise. It's crucial to strategically plan riverside development to minimize noise-sensitive activities near major noise sources. Technological advancements, including quieter technologies and real-time noise monitoring systems, play pivotal roles in implementing effective noise management strategies. Challenges like balancing economic development with noise reduction, ensuring enforcement of regulations, and fostering community involvement underscore the complexity of achieving sustainable noise management in rivers like the Ganges and Brahmaputra. Ultimately, integrating these approaches offers a pathway to safeguarding freshwater ecosystems and supporting the communities reliant on them. [8][15]

More concern on river dolphins (why?)

River dolphins face severe threats to their survival, primarily due to habitat loss, pollution, and human activities. Pollution, including underwater noise (URN), poses a significant additional risk to their dwindling populations. Unlike some fish, river dolphins heavily rely on echolocation for crucial functions such as navigation, communication, and prey detection, making them particularly vulnerable to disruptions caused by URN. Beyond their ecological role, river dolphins serve as bioindicator species[22], offering insights into the overall health of freshwater ecosystems; their decline often signals broader environmental issues. Moreover, these creatures hold profound cultural and spiritual significance for communities residing along rivers, being revered as symbols of good luck and river health. Efforts to conserve river dolphins not only aim to protect biodiversity but also have potential economic benefits through sustainable dolphin tourism. Well-managed tourism can generate income for local communities, providing a direct incentive for conservation while also raising awareness about the plight of these endangered or critically endangered species. *(Source: WWF, IUCN Red list threatened species - Platanista gangetica)*

Ganges river dolphin

The Ganges River Dolphin *(Platanista gangetica),* called as 'the tiger of Ganges', is one of the world's oldest surviving cetaceans, having evolved over 20 million years ago. It is an apex predator in a vast interconnected river system in three countries. It is listed as 'Endangered' on the IUCN Red List of Threatened Species. It is an inhabitant of the Ganges, Meghna Brahmaputra, and Karnaphuli river systems of the Asian subcontinent. [3]

This species has extremely poor eyesight and relies almost entirely on echolocation to navigate and locate prey. Externally, the eye appears to be barely larger than a pinhole, restricting light from reaching the retina. There is no lens, and the optic nerve is very narrow, leading scientists to conclude that their eyes are incapable of forming clear images, but that they may still serve as light receptors. [3]

The distributional range of the Ganges River dolphin includes over 10,000 km of the Ganges-Brahmaputra-Meghna, and Sangu-Karnaphuli River systems in Bangladesh, India and Nepal. Ganges river dolphins are commonly found in deeper sections of river, they prefer eddies around islands, river bends and confluences which are often also the places that people prefer to fish. Now dams and barrages restrict dolphin movement, but in the past during the monsoon season, the dolphins would have moved upstream into smaller rivers, and then back downstream to larger river channels in the low water winter season. [3]

URN effects on the Ganges River dolphin

During the dry season, when water levels are lower, the effects of vessel noise are most pronounced. This period coincides with increased vessel traffic, exacerbating the challenges faced by dolphins due to noise pollution. One of the primary consequences of this noise pollution is the masking of echolocation clicks, which are crucial for dolphins to navigate their environment and locate prey. Previous studies reveal that as noise levels rise, dolphins experience significant metabolic costs in their efforts to compensate for the disrupted acoustic signals. These metabolic costs can have far-reaching implications, potentially affecting the dolphins' ability to efficiently forage and maintain their energy reserves, essential for their survival.

Behavioural responses to increased noise include alterations in acoustic activity patterns. Dolphins tend to suppress their acoustic signals when noise levels exceed certain thresholds, possibly to avoid expending additional energy in futile attempts to communicate or echolocate effectively amidst the noise. Such behavioural changes not only impact individual dolphins but can also disrupt social interactions and communication within dolphin populations, which are critical for their social structure and reproductive success.

In addition to vessel noise, the studies also address the impact of dredging activities aimed at maintaining or deepening river channels. These activities contribute additional noise and physical disturbance to dolphin habitats, further complicating their ecological challenges. Observations indicate that dolphins may avoid areas subjected to dredging, highlighting their sensitivity to such disturbances.

Mitigation strategies proposed in the study encompass technological advancements aimed at reducing vessel noise emissions, such as improving propeller efficiency to minimize cavitation noise that overlaps with dolphin communication frequencies. Regulatory measures, including the implementation of speed limits in critical dolphin habitats during sensitive periods, are also suggested to mitigate noise propagation and collision risks with vessels.

Furthermore, the studies advocate for habitat management practices that prioritize maintaining natural river depths and flows. This approach aims to reduce the need for extensive dredging, which can disturb riverbed sediment and impact fish populations, upon which dolphins depend for their food supply. Public awareness and policy advocacy are deemed essential in integrating these mitigation measures into large-scale waterways development projects. The study underscores the importance of considering the ecological impacts of such developments, particularly on endangered species like the Ganges River dolphin, which serves as a flagship species for river conservation efforts in India.[1]

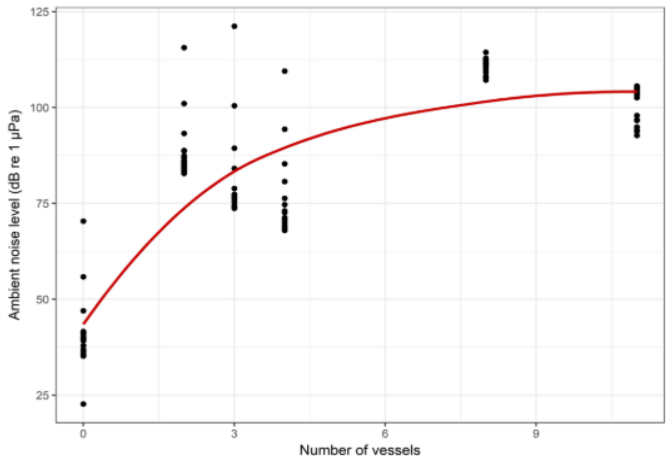

Figure 1. A non-linear relationship was found for the number of vessels plying and the corresponding ambient noise level. The highest degree of increase would occur until 4 to 5 vessels, beyond which the ambient noise level reached an asymptote.

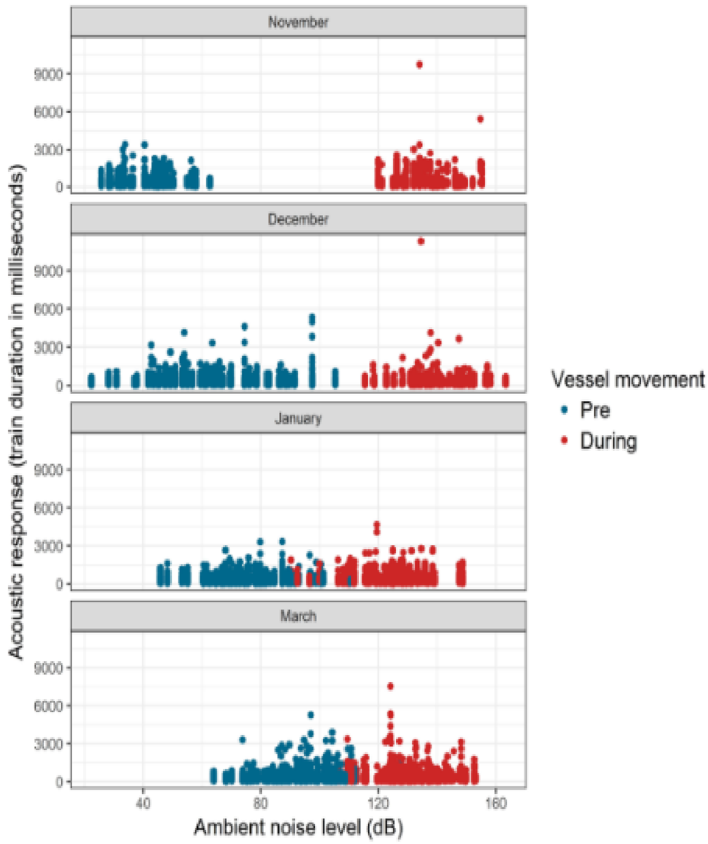

Figure 2. From November to March, as river discharge reduced, vessel traffic increased, and ambient noise levels increased, the magnitude of difference reduced substantially in the 'pre' and 'during' phases for an acoustic response (train duration) at the reference site (Kahalgaon).

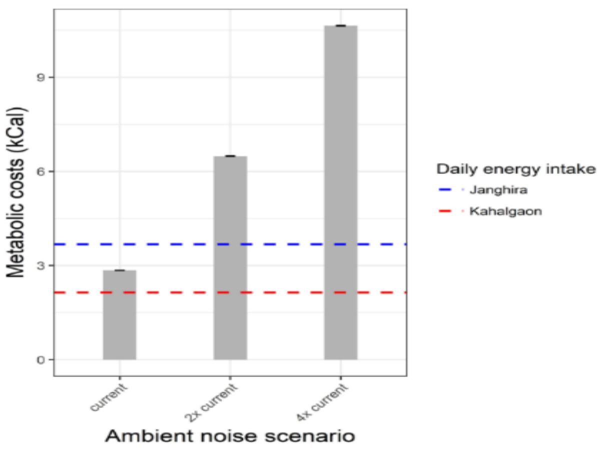

Figure 4. A comparison of the metabolic costs of clicking in altered acoustic environments between Kahalgaon (deep–noisy) and Janghira (deep–quiet). In Kahalgaon, where feeding rates were lower than Janghira, maintaining continuous altered acoustic activity in current ambient noise levels was costlier, given the natural feeding intake of a dolphin (dashed lines).

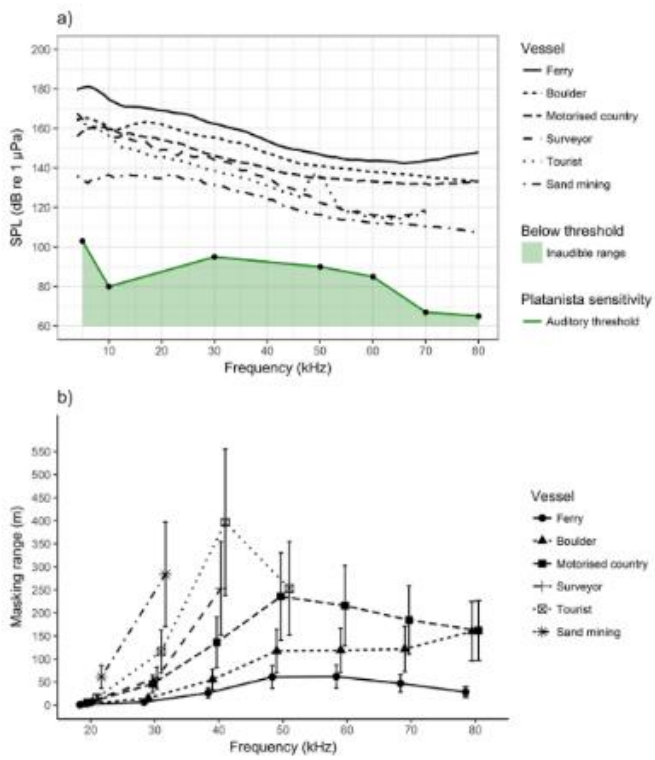

Figure 3. (**a**) The graph depicts the sound source level of different types of vessels at 1 kHz frequency bins, with line in green indicating the threshold level of hearing for *Platanista*[59]. The green shaded area represents the inaudible zone. (**b**) Maximum masking ranges varied between 50 m and 400 m for frequencies from 40 to 80 kHz. Error bars represent 95% CI and are based on the "transmitter" dolphin's distance (modelled for 2–10 m) from the vessel. The strongest masking effects on *Platanista* clicks were estimated for slow-moving vessels such as ferries and motorized country boats.

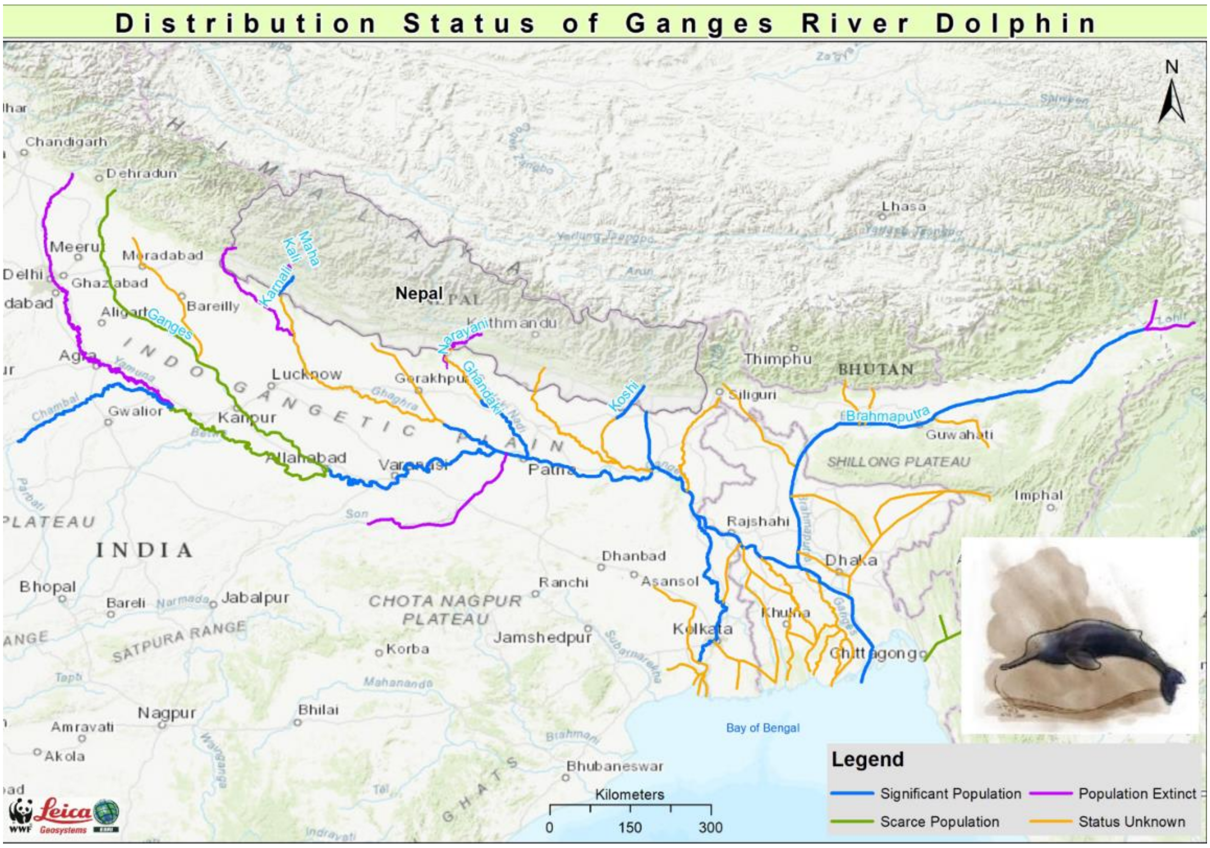

Figure 5. Map of distribution status of Ganges River dolphin

Political Significance

National Aquatic Animal of India: The Ganges River Dolphin holds a prestigious position as the national aquatic animal of India (source: WWF). This designation highlights its national importance and raises awareness about the need for its conservation.

Flagship Species: The Ganges River Dolphin serves as a flagship species for river conservation efforts in South Asia (source: WWF). Its endangered status draws attention to the overall health of the river ecosystems and the need for stricter environmental regulations.

Transboundary Cooperation: The dolphin's range spans across India, Nepal, and Bangladesh, necessitating international cooperation for its conservation (source: WWF). This fosters collaboration on river management practices and pollution control strategies.

Economic Importance

Ecotourism Potential: Healthy dolphin populations can attract tourists interested in responsible wildlife viewing, generating revenue for local communities (source: WWF). This can provide economic incentives for sustainable river management practices.

Fisheries: Dolphins play a role in maintaining healthy fish populations by preying on weak or sick fish, promoting overall fish population health. This indirectly supports fisheries which are a vital source of income for many communities (source: WWF).

Cultural Importance

Religious Significance: In Hinduism, the Ganges River is considered sacred, and dolphins are sometimes seen as protectors of the river (source: WWF). This cultural reverence can inspire local communities to participate in conservation efforts.

Folklore and Mythology: Dolphins are often featured in local folklore and mythology, weaving them into the cultural fabric of the region (source: WWF). Their presence can strengthen the connection between people and the river.

Environmental Importance

Indicator Species: The health of Ganges River Dolphin populations reflects the overall health of the river ecosystem (source: WWF). They are sensitive to water quality, pollution levels, and habitat degradation, acting as an indicator of environmental well-being.

Predatory Role: Dolphins help maintain a healthy balance in the river ecosystem by preying on weak or sick fish, promoting overall fish population health (source: WWF).

WWF's River Dolphin Rivers Initiative aims to stop and reverse the decline of river dolphin populations in South America and Asia by 2030. The initiative targets three major threats: unsustainable fisheries, hydropower and infrastructure development, and pollution. WWF plans to leverage its conservation expertise and global partnerships to secure the future of river dolphins and their freshwater habitats. In India and Nepal, WWF collaborates with governments, experts, civil society, and local communities to protect river dolphin habitats through scientific research, community-led conservation, species monitoring, policy advocacy, and outreach. WWF-India focuses on promoting Best Management Practices in irrigation and advocating for better habitat protection. A key initiative involves advocating for Environmental Flows to sustain river ecosystems and their services. [3]

The Indian government announced Project Dolphin in 2020 to reverse the decline in species numbers – aiming to emulate the conservation successes achieved by Project Tiger and Project Elephant. India is also a signatory to the Convention on Migratory Species (CMS), which includes the Ganges River Dolphin in Appendix I, requiring efforts to strictly protect it. Several dolphin sanctuaries have been established along the Ganges River, like Vikramshila Gangetic Dolphin Sanctuary in Bihar, offering some level of habitat protection. [3]

Meanwhile, the World Bank is funding WWF to conduct a major study to agree upon the global best practices to sustainably conserve each river dolphin species based on the latest science and extensive engagement with stakeholders, including those in Bangladesh, India and Nepal. The aim of all these efforts is to ensure that the Ganges River dolphin does not follow the Yangtze River dolphin into extinction. But it is not just about preventing the loss of an extraordinary species; saving the Ganges River dolphin will save so much more. As the apex predator, it is a key indicator of the health of its rivers – and plays a vital role in those critical ecosystems. A thriving population of river dolphins will mean that the health of these vital river systems is improving – benefiting hundreds of millions of people as well as a huge diversity of other species from mahseers to mangroves and migratory birds.[3]

Way ahead

Research on other freshwater living beings: It is imperative to broaden our research focus beyond dolphins to encompass a diverse array of freshwater species. Exploring the effects of underwater noise (URN) on fish, invertebrates, amphibians, and reptiles inhabiting rivers, lakes, and associated ecosystems will provide a comprehensive understanding of species-specific responses and guide effective management strategies.

Exploring natural means of mitigation: Additionally, investigating how forests and mangrove forests along water bodies act as natural sound barriers or absorbers is crucial. These habitats may play a significant role in mitigating URN impacts on freshwater species, informing conservation efforts and restoration initiatives.

Study on propagation of sound: Understanding the propagation of sound through rivers and lakes is another priority, as it will elucidate how URN travels, attenuates, and reflects in different freshwater environments, thereby influencing the exposure of aquatic organisms. It also enables effective monitoring of aquatic life and environmental changes, facilitates underwater communication systems and sonar technology for navigation and research, aids in mapping underwater topography, supports the design of hydroelectric facilities while minimizing environmental impact, and contributes to seismic studies for hazard assessment. By comprehending how sound travels through freshwater environments, we can better manage and protect these ecosystems while leveraging their resources sustainably.

Study on biological criticality: Research focusing on the developmental stages of aquatic species—such as immature growth, reproduction, and egg viability—will provide insights into the long-term impacts of URN on population dynamics and ecosystem health.

Building spatial planning frameworks: There is a pressing need to implement inland water spatial planning frameworks, like Maritime Spatial Planning (MSP), to manage competing uses and mitigate URN impacts effectively. Thought MSP can be initial tool of reference, spatial planning in freshwater systems have their own characteristics to consider. Integrating URN considerations into spatial planning will promote sustainable development and conservation of freshwater ecosystems.

Interdisciplinary collaborations: Policy and regulatory frameworks tailored to URN management in freshwater systems are essential, encompassing noise mitigation measures, robust monitoring protocols, and effective enforcement mechanisms to safeguard aquatic biodiversity and ecosystem integrity. Developing effective frameworks for managing underwater noise in freshwater systems involves several key steps. Begin by identifying and engaging stakeholders such as local communities, NGOs, industry representatives, and government agencies through consultations to gather diverse perspectives and ensure inclusivity. Conduct scientific research to establish baseline data on noise levels and their impacts on aquatic life. Use these findings to inform the development or revision of policies and regulations that prioritize noise reduction and ecosystem conservation. Educate and involve local communities to foster support and understanding. Ultimately, integrating URN management into future sustainable development plans for inland waters is crucial. This integration should involve interdisciplinary research collaborations, stakeholder engagement, and adaptive management strategies to ensure the long-term conservation and sustainable use of freshwater resources.

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Image source: Figure 1 – 4: *Dey, Mayukh & Krishnaswamy, Jagdish & Morisaka, Tadamichi & Kelkar, Nachiket. (2019). Interacting effects of vessel noise and shallow river depth elevate metabolic stress in Ganges River dolphins. Scientific Reports. 9. 15426. 10.1038/s41598-019-51664-1.* ***Figure 5:*** Ganges dolphin brief 2021, WWF, https://wwfint.awsassets.panda.org/ganges_dolphin_brief_2021

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