



# Ocean Governance in the Indian Ocean Region – An Alternate Perspective

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*Marine species are known to use acoustic signals for biologically critical functions such as foraging, communication, navigation, etc. The unregulated maritime activities in the Indian Ocean Region (IOR) are translating into a rapid rise in the ambient noise and consequent acoustic degradation of the marine ecosystem. The environmental conservation initiatives are seen to be in direct conflict with the economic growth imperatives and are thus faced with significant political opposition. The lack of awareness regarding the acoustic aspect of the marine ecosystem towards generating credible underwater domain awareness is a major cause of concern and limits the effectiveness of any conservation efforts. Further, the IOR with its tropical littoral waters presents suboptimal performance of the underwater sensors deployed to generate underwater domain awareness. The authors attempt to provide an alternate perspective of the acoustic degradation of the marine ecosystem as a result of heightened maritime activities in the IOR. The complexities of formulating the regulatory framework and associated monitoring mechanism are also discussed.*

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## Introduction

Natural law theorist Hugo Grotius, in his 1609 study *Mare Liberum*, argued that “the sea cannot become private property and that no part of the sea can be considered as the territory of any people whatsoever”.<sup>1</sup> Thus, what belongs to all requires effective governance to ensure equitable resource exploitation to avoid conflict and ensure sustainable growth.<sup>2</sup> Ocean governance has always been a challenge for policy-makers and has been the subject of evolution in response to advances in scientific knowledge and the ever-increasing human need to dig deep for undersea resources.<sup>3</sup> Ocean management has to take into account multiple factors including scientific uncertainties, economic globalisation, limitations of natural resources, modern technology, population pressures and innumerable new challenges. Noise pollution in the ocean presents another new challenge.<sup>4</sup>

Marine species are known to use sound for biologically significant activities such as foraging, navigation, communication, etc.<sup>5,6,7</sup> The higher levels of ambient noise are masking their ability to perceive the environment around them, and causing psycho-acoustic disorientation, stress and fatalities.<sup>8,9,10</sup> Ambient noise in the ocean is contributed by various sources with different spectral characteristics.<sup>11,12</sup> Since the natural sources of noise such as wind, rain, biological sources, etc. are steady sources that remain predictable for marine species, the inhabitants of the marine ecosystem adapt to these sources. On the other hand, anthropogenic noise sources like shipping, industrial activities in coastal waters, seismic activities, sonar transmissions, etc. are a cause of concern for the marine habitat as there has been an indiscriminate increase in these activities linked to the so-called economic growth index.<sup>13,14</sup> Noise in the ocean has yet to be recognised as a pollutant, and thus effective regulations on the subject have not been instituted, to date.<sup>15,16,17</sup>

The Indian Ocean Region (IOR) presents unique challenges in terms of a lack of credible scientific inputs to initiate any efforts towards the formulation of a regulatory framework. To add to that, suboptimal sensors for underwater domain awareness is a significant limitation and even ensuring effective monitoring mechanisms are considered very vital for implementation of regulations.<sup>18</sup>

Ocean governance is a subject that necessitates seamless participation from the scientific, legal and environmental fraternities, as well scrutiny from the general public. In the IOR, public awareness on this issue is abysmally low and, to compound the predicament, the 21<sup>st</sup> century is seeing an indiscriminate rise in maritime

activities. The lack of regulation can have a serious impact on the marine ecosystem, specifically to their acoustic habitat, resulting in unsustainable growth and irreversible damage.

The paper attempts to offer a perspective on the concerns due to acoustic degradation associated with heightened maritime activities in the IOR. The multiple facets of the challenges, the regulatory framework and the monitoring mechanism are also discussed.

## **Anthropogenic Noise and Marine Species**

Ambient noise is the average level of background noise which is observed over a prolonged duration. It does not take into account momentary fluctuations due to transient sources. Ambient noise in the ocean varies with location and frequency and can be categorised as coming from natural sources and man-made (anthropogenic) sources.<sup>19</sup>

The most dominant anthropogenic noise is from distant shipping, in the low-frequency band from 10 Hz to 2.5 kHz. Seismic explorations to probe deep into the seabed also use low-frequency sound (below 100 Hz). Other sound sources include air guns, vibroseis and explosives. Acoustic Thermometry of Ocean Climate (ATOC) measures the global ocean temperature using low-frequency sound. Sonar transmissions vary from mid (1–25 kHz) to high (beyond 25 kHz) for both military and commercial applications.

The propagation characteristics of the underwater ocean environment cause high attenuation of the signals at higher frequencies. Consequently, with increasing frequency, the ambient noise spectrum levels decrease from about 140 dB re 1  $\mu\text{Pa}^2/\text{Hz}$  at 1 Hz to about 30 dB re 1  $\mu\text{Pa}^2/\text{Hz}$  at 100 kHz. Lower attenuation in the low-frequency band translates to larger propagation ranges and thus has much wider impact undersea.<sup>20</sup> The low-frequency sound sources like the distant shipping noise have a much bigger influence on the background noise. [Figure 1](#) presents the detailed ambient noise spectrum in the deep oceans. The plot has underwater noise curves developed by the US Navy in the 1960s, and has been modified to reflect modern levels of shipping noise (shaded area), that exceed natural wind noise, for higher sea states (numbered curves).

According to documented data, there are more than 90,000 ships of different types larger than 100 gross tons in the world, and each introduces noise into the

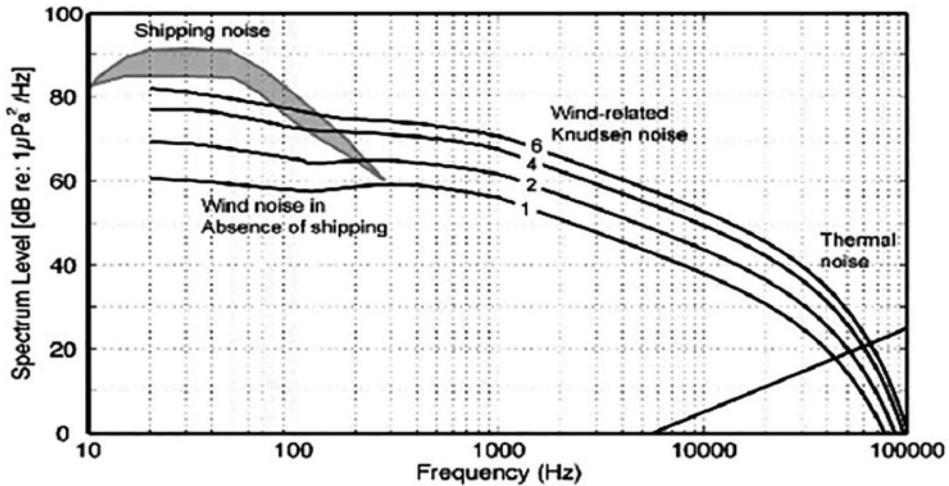


Fig. 1. Ocean Ambient Noise for Frequencies between 10 and 100 KHz. *Source:* Proceedings of the International Workshop on Shipping Noise and Marine Mammals, A Background Paper Produced by Participants of the International Workshop on Shipping Noise and Marine Mammals. Accessed on 18 April 2105.

marine environment.<sup>22</sup> Commercial ships generate underwater noise as an incidental byproduct of their operation, and with their increase in both number and size, the noise in the oceans is only rising.<sup>23</sup> Based on deepwater studies in the Northeastern Pacific (see Figure 2), low-frequency background noise in each of the past four decades has approximately doubled (i.e. an increase in power of 3 dB).<sup>24,25</sup> The well-distributed nature of shipping operations globally and the low-frequency characteristics of the spectrum further ensure that the impact is near universal. The continuous infrastructure development required to support the increasing shipping traffic is further increasing the ambient noise due to nonstop activities in the coastal areas which are the prime habitats of the affected species.

The increased ambient noise in the ocean can potentially mask biologically significant sounds (i.e. it can interfere with clear reception of signals of interest). Masking could disrupt breeding in marine species that use acoustic signals during mating and reproduction, and disturb foraging in animals that use sound to detect prey. Also, noise can mask important environmental cues that these marine species use to navigate and sense their surroundings – even sounds that are used to identify predators. The more frequent whale stranding being observed across various locations is attributed to masking of the wave breaking the shore sound that disorients whales,

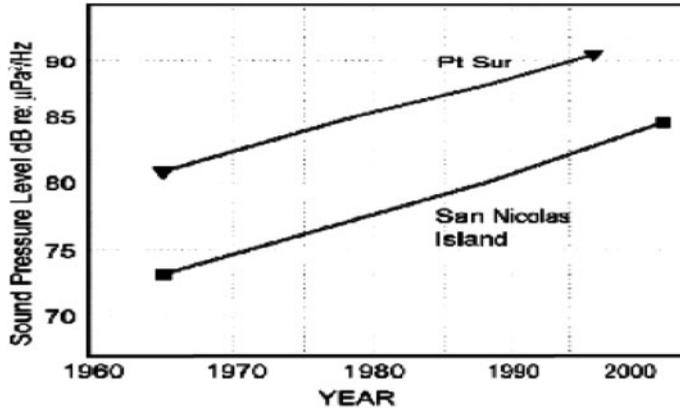
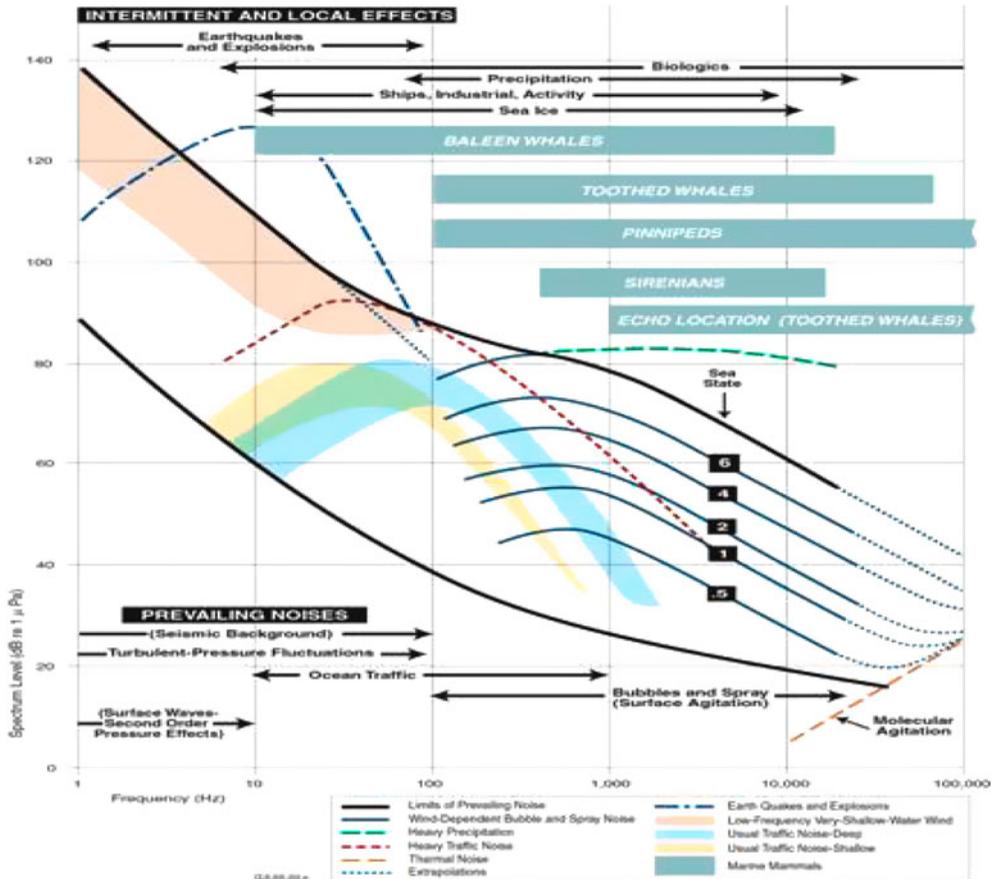


Fig. 2. Ocean Ambient Noise Measurement at Two Sites off California. *Source:* Proceedings of the International Workshop on Shipping Noise and Marine Mammals, Shipping Noise and Marine Mammals”, A Background Paper Produced by Participants of the International Workshop on Shipping Noise and Marine Mammals. Accessed on 18 Apr 2105. Point Sur (Pt Sur) Lightstation is a lighthouse at Point Sur, California, 135 miles (217 km) south of San Francisco.

leading to their stranding in large numbers. One question that may be asked by sceptics could be that the sound source and the marine hearing may not match to have any negative impact. However, these species may adapt to changes in their surroundings. Figure 3 presents a spectral representation of various marine species and the numerous ambient noise sources.<sup>26</sup>

Some species adapt their communication signals to avoid being masked by ambient noise; however, the extent of such alterations is constrained behaviourally and environmentally. Marine mammal communication systems evolve to maximise the ability for species to recognise biologically meaningful sounds relative to the background noise; thus, these adaptations also represent suboptimal behaviours. These alterations can be presumed to be a threat to survival and even to reproductive success. The rapid rise in shipping over the last couple of decades may not have given enough time to some of these species to adapt to the noisier ocean.<sup>27</sup>

Figure 4 shows an example of predicted decreased communication ranges for baleen whales, owing to increase in ambient noise due to shipping. Hearing capabilities have been studied for 22 of the approximately 125 species of living marine mammals, and baleen whales are thought to be most sensitive to low-frequency sounds (10 to 1000 Hz).



**Fig. 3.** Overlap of Frequencies Generated by Marine Mammals and Produced by Anthropogenic Activities. *Source:* The source of image has been acknowledged as per standard protocol. The website is the source of the image. Black & White picture may not be able convey all the information desired. [http://www.whoi.edu/science/MPC/dept/research/ocean\\_noise/sourcesofsound.html](http://www.whoi.edu/science/MPC/dept/research/ocean_noise/sourcesofsound.html). Adapted from G.M. Wenz, “Acoustic Ambient Noise in the Ocean: Spectra and Sources,” *Journal of the Acoustic Society of America* 34 (1962): 1936–1956. Overlay of marine mammal “activity” ranges added by David Bradley, Applied Research Laboratory, Penn State University.

### Focusing Events

Historical attempts at policy change have been preceded by massive public outcry and subsequent political pressure. This section attempts to highlight how, elsewhere in the world, the issue of ocean noise and its effects became a matter of global concern and captured the attention of policy-makers both within and outside governments.



Fig. 4. Estimated Reduction in Baleen Whale Communication Range from Prior to the Advent of Commercial Shipping (Left) to the Expected Ranges of Today (right). Source: Proceedings of the International Workshop on Shipping Noise and Marine Mammals, held by Okeanos –Foundation for the Sea, at Hamburg, Germany, April 21–24, 2008. <http://www.okeanosfoundation.org/assets/Uploads/Hamburg-shipping-report-2.pdf>. Black & White picture may not be able convey all the information desired.

Aspects such as noise pollution in the oceans were highlighted as problems of public concern through the effective use of focusing events by activists. “Key events that cause members of the public as well as elite decision makers to become aware of a potential policy failure” have been referred as *focusing events*.<sup>28</sup>

Nongovernmental organisations (NGOs) have played a major role in shaping public opinions. The Natural Resources Defence Council (NRDC) of the US has played a significant role in creating awareness and even effectively leading opposition to anthropogenic ocean noise. The NRDC’s 1999 publication of a book entitled *Sounding the Depths – Super Tankers, Sonar and the Rise of Undersea Noise*<sup>29</sup> is widely considered a significant contribution to the noise pollution issue. It is the first such work that highlights underwater noise as a type of pollution and comprehensively brings out the impact of experimental and military sonars, and noise from shipping, oil exploration and other marine-related activities. The book emphasises the requirement for proactive policies for regulation of underwater sound. The Humane Society of the US has conducted major campaigns to protect marine mammals from noise pollution, and is one of world’s largest animal protection organisations.<sup>30</sup>

### *The Ship Shock Test*

Public attention regarding ocean noise pollution is considered to have started in 1993 with the US Navy's Ship Shock program. Ship shock testing to ascertain the strength of the hull and ship systems onboard naval vessels necessitates the detonation of underwater explosives at various distances from a platform. The NRDC and others filed a suit to stop the Navy from conducting the ship shock trials of the US AEGIS-class destroyer *John Paul Jones*. The court accepted that there was a failure to consider alternate sites for the testing in violation of the Marine Mammal Protection Act. The Navy was compelled to conduct surveys to determine the optimal area for the tests, carry out more stringent monitoring and prepare an environment impact statement (EIS) for the remaining trials after completion of the first test at a location recommended by the NRDC.<sup>31</sup>

### *Acoustic Thermometry of Ocean Climate*

Acoustic thermometry of the ocean climate (ATOC) to measure global warming, using low-frequency signals, was developed by the scientists at the Scripps Institute of Oceanography in San Diego, in the early 1990s. The measurements entail the transmission of low-frequency acoustic signals in the ocean and their processing by receivers thousands of kilometres away. The analysis was based on the direct correlation of the sound velocity profile with the water temperature, that would be able to record long-term changes in ocean temperatures and deduce valuable information about global warming. Biologists at Dalhousie University launched an internet campaign on the possible impact of the ATOC transmissions on marine mammals in February 1994, prior to the commencement of the operations. It created significant public pressure, with senators publicly condemning the ATOC program and some members of Congress threatening to slash the budget of the National Ocean and Atmospheric Administration (NOAA). NRDC stepped in and lobbied vigorously to redirect resources to the study of sound in whales and other marine mammals, resulting in a delay of the ATOC operations until a draft environment impact statement (DEIS) was prepared. The negotiations that followed, between Scripps and the NGOs, resulted in measures to mitigate potential harm to marine mammals, and the redistribution of funds for a major study on the effects of low-frequency sound on marine mammals.<sup>32</sup>

*Greek Whale Strandings and NATO*

The key international focusing event involving underwater sound took place in 1996, along the coast of the Kyparissiakos Gulf in Greece, involving the stranding of a number of Cuvier's beaked whales alive on a 38-km stretch of beach, and the subsequent death of seven animals. The event was attributed to a joint international experiment using a high-powered, low-frequency sonar by the US Navy and the North Atlantic Treaty Organization (NATO) being conducted at the same time. The same attribution was made by Dr. A. Frantzis, a biologist at the University of Athens, in a correspondence to the journal *Nature*, entitled "Does acoustic testing strand whales?"<sup>33</sup> The incident acted as a focusing event, highlighting the issue of unregulated underwater sound, though a direct link could not be established between the use of sonar and the whale deaths. In addition, the event underscored the challenges of regulating the underwater ocean noise in the presence of a transboundary "pollutant" in the international arena with a complex mix of dynamics: the sonar was owned by the US government; the ship was owned by the 16 NATO nations; the experiment was carried out in Greek waters; and the ship flew a German flag.<sup>34</sup>

Regardless of the outcome of these programmes discussed above, and many more, these events have played a critical role as drivers of discussion and policy analysis with respect to underwater noise pollution. NGOs, primarily the NRDC and some others, have made major contributions in drawing the attention of governments and international organisations like the NATO, the United Nations (UN) and many more to the issue of ocean noise pollution.<sup>35</sup>

**Current Regulatory Status**

The increasing reliance on marine resources, well-supported by technological advances, mandates international management of ocean activities. Typically, ocean management can be undertaken unilaterally, bilaterally, regionally or globally. Unilateral measures by local governments and bilateral agreements among neighbouring nations with shared seas are commonly used for coastal zone planning, undersea resource management and environmental protection. Ocean issues such as biodiversity, sustainable use of ocean resources, fisheries and pollution are presently being addressed through more than 200 regional agreements.<sup>36</sup>

The 1982 UN Convention on Laws of the Sea provides a framework for addressing ocean noise pollution; however, precious little has been done under the UN banner to ensure that ocean noise emission is regulated effectively. In 1985, the United Nations Environmental Programme (UNEP) called on the international community to address the long-term threat of anthropogenic noise in the ocean, and published *Marine Mammals: Global Plan of Action*.<sup>37</sup> The report highlighted the

*possibility that underwater noise from vessels and other human activities such as geological surveying by sonic techniques can constitute a form of noise pollution to which the cetaceans may be seriously sensitive on account of their dependence on acoustic processes for such purposes as communication and location of prey.*<sup>38</sup>

Numerous studies have been initiated by UNEP; however, no clear regulatory framework has been proposed. In 1988, the global plan of action for marine mammals was reviewed by UNEP and found to be unsatisfactory. The cause of failure was primarily attributed to lack of funds and multiple other factors including changing government priorities, severe budget constraints, a lack of clear framework for action and insufficient effort by all collaborators.<sup>39</sup>

The International Maritime Organization (IMO), being the most significant regulatory body for international shipping and with its marine pollution (MARPOL) protocol of 1978, only recognises substance pollution through its six annexes. The radiated noise of marine vessels is yet to be identified as a pollutant, and, due to the lack of a credible and quantifiable cause and effect database, the regulatory framework has not yet materialised. In 2002, the IMO through its resolution A.927 (22) accepted noise as a hazard. It instituted the concept of “Particularly Sensitive Sea Areas” (PSSA) and designated five areas as PSSAs: the Great Barrier Reef, Australia; the Sabana-Camaguey Archipelago, Cuba; Malpelo Island, Colombo; the Florida Keys, United States; and the Wadden Sea in North Europe. The PSSA guidelines designate a category of special measures that incorporate speed limitations and special construction requirements that could potentially be directed toward controlling acoustic emissions. However, to date, the IMO has not specifically addressed noise as a threat to any of the PSSAs.<sup>40</sup>

The International Whaling Commission (IWC) addressed the issue of disturbance to marine mammals by noise generated during whale watching activities. In 1996, IWC specifically noted that

*cetacean species may respond differently to low and high frequency sounds, relative sound intensity or rapid changes in sound; vessel operators should be aware of the acoustic characteristics of the target species and of their vessel under operating conditions; particularly of the need to reduce production of potentially disturbing sound as far as possible.*<sup>41</sup>

In spite of these warnings, the IWC has yet to make any policy framework on noise and whales. To date, no scientific research on the effects of noise on marine mammals has been promulgated by the IWC.

The International Council for the Exploration of the Sea (ICES) formed a study group to address the concern over the effects of underwater noise radiating from research vessels. The interim report produced by the study group in 1993 was submitted to the statutory meeting in Dublin, and it recognised that insufficient information was available to fully address the mandate that “research vessel[s] engaged in underwater observations and measurements need to be quiet and should not impact the species being studied”.<sup>42</sup> A Cooperative Research Report No. 209 (CRR-09), edited by R. B. Mitson,<sup>43</sup> brought out in detail the impact of radiated noise on several species and tried to formulate a benchmark for the radiated noise of research vessels. The report deals with the radiated noise of a marine vessel with its significant contributors, and presents the acoustic hearing levels of various marine mammals. The proposed underwater radiated noise specification at 11 knots free-running for all vessels, along with a comparison of radiated noise of certain research vessels used in fisheries research, is presented in [Figure 5](#).

The European Union has addressed the issue of ocean noise in the context of habitat conservation.

*The European Council Directive 92/43/EEC, on the Conservation of Natural Habitats and of Wild Fauna and Flora, requires Member States to take measures to prevent inter alia deliberate disturbance of cetaceans. This directive lists all species of cetaceans as in need of strict protection.*<sup>44</sup>

Recently, several regional agreements have addressed the issue of ocean noise pollution: the OSPAR Convention, the Arctic Council, Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and

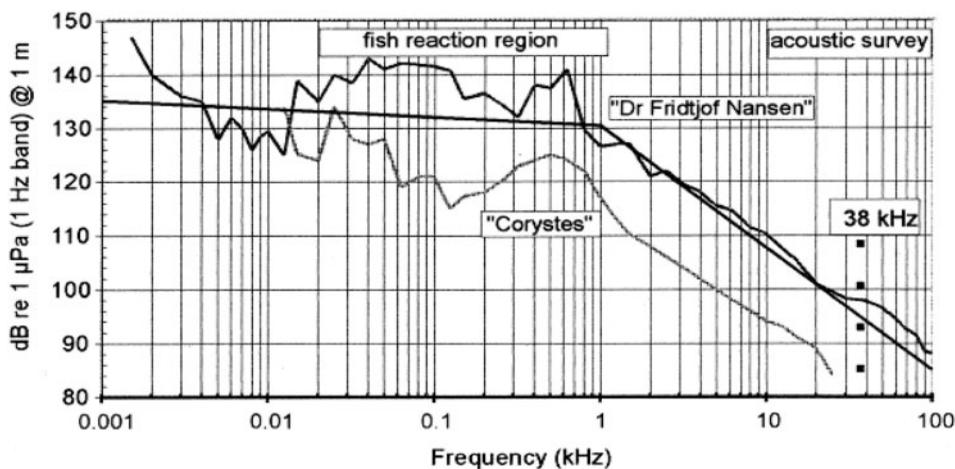


Fig. 5. Noise Signatures at 11 Knots of Two Modern Research Vessels Against the Proposed Radiated Noise Specification. *Source:* R.B. Mitson, ed., *Underwater Noise of Research Vessels: Review And Recommendations*, Cooperative Research Report, No. 209 [Council for the Exploration of the Sea (ICES), 1995].

contiguous Atlantic area (ACCOBAMS), etc.<sup>45</sup> However, due to the transborder nature of ocean noise, these regional agreements will be insufficient to monitor and regulate effectively. A much broader framework under the UNEP or the IMO needs to be worked out in line with CRR-09 by ICES.

### Challenges in the IOR

Ports in the Indian Ocean handle about 30% of global trade, and 50% of the world's container traffic traverses the IOR. Furthermore, the Indian Ocean has some of the world's most important choke points: the Strait of Hormuz, the Strait of Malacca and the Bab-el-Mandeb. These choke points are strategically important for global trade and energy flow, and a number of extraregional states maintain a naval presence in the Indian Ocean. Consequently, the region maintains a significantly high shipping traffic throughout the year. Higher traffic translates to higher ambient noise in the ocean. The marine industry, with its diverse sectors including fishing, mineral exploration, research and exploitation, manufacturing, ports etc., has been a weak area so far in the

IOR. However, with the oceans being seen as the new economic frontier, there is a great rush to reach out in the IOR.

The complex propagation characteristics of acoustic signals in the tropical waters of the IOR result in suboptimal performance of the underwater sensors. The lack of Research & Development efforts and credible oceanographic studies backed by field experiments has been a major reason for suboptimal sensor performance manifesting in poor underwater awareness and resource mapping. It is worth mentioning that importing technology cannot solve the problem and only extensive onsite R& D efforts and indigenous technology can provide effective inputs for sustainable undersea exploration and exploitation.<sup>46</sup>

The marine conservation efforts in the IOR are largely led by marine biologists, with limited understanding of the acoustic aspects. All marine species deaths are attributed to reasons best known to the marine biologists, and there seems no effort to explore the possibility of psycho-acoustic stress being a contributing factor. Such an approach is highly limited. A multidisciplinary approach and collaborative way ahead needs to be formulated, with active participation by all stakeholders such as marine biologists, acoustic experts, oceanography experts, legal experts, ship handlers, environmental activists and many more. The transborder nature of underwater noise further limits the efficacy of any particular nation or government taking the lead and initiating measures towards arresting the ongoing degradation. The IOR has a volatile and unstable political dispensation, with the nations in the region having their focus still restrained by multiple basic issues of poverty alleviation, health for the masses, food security, energy security and much more, leaving them with no opportunity to think beyond and address such relevant but “not immediate” concerns.

Further, the marine eco-concern discussed in the paper is based on studies elsewhere, in the other oceans. Minimal scientific data is available regarding the status of marine habitat in the IOR. The extrapolation of the scientific inputs is useful only to create awareness and highlight the importance to the stakeholders. No concrete conservation efforts or attempts at a regulatory framework are possible without significant data on the local conditions. Data on the ambient noise source characteristics and the trends for the IOR do not exist. Even inputs on marine mammal hearing are highly limited. The marine biologists in the region more often than not work in isolation, and acoustic analysis is seldom part of their study. The available literature is highly limited on the acoustic aspect of the marine ecosystem.

Heightened maritime activity in the absence of regulation can be disastrous for a sustainable growth model; however, in the absence of credible scientific inputs, effective regulatory framework is not practically possible. The weak economies of the IOR countries do not encourage political leadership to be environmentally conscious; who could invest substantial resources for R& D at the cost of economic growth? The implementation of regulations in the maritime domain further add to the challenges due to the costly infrastructure required for maintaining an effective monitoring mechanism in the unforgiving and corrosive marine environment.

### Way Ahead

The situation in the IOR is a cause for concern when it comes to regulations on noise pollution in the oceans. An extensive debate on the suggested way ahead by multidisciplinary thinkers and strategists to evolve a comprehensive action plan could be as follows:

1. Effective sensors

The effectiveness of underwater sensors in the IOR, with tropical littoral waters, is a major concern for any study. Extensive oceanographic surveys and signal processing efforts are necessary to enhance the effectiveness of acoustic sensors.

2. Ambient noise sources

Ambient noise source characterisation locally has to be undertaken and detailed analysis carried out on trends with long-term data collection. A mechanism has to be instituted for data collection with sustainable undersea infrastructure. Shallow-water ambient noise presents highly site-specific behaviour, so no generalisation is possible.

3. Acoustic characterisation of marine species

Marine species in the region have to be identified and their acoustic signal characteristics and hearing abilities have to be understood. This will require extensive surveys and field work to ascertain the acoustic behaviour of the local marine species. The vulnerable species have to be identified based on their ambient noise characterisation. Psycho-acoustic studies will have to be initiated for varied species.

4. Acoustic habitat assessment

The detailed acoustic source and bio-acoustic receivers have to be evaluated to evolve the dynamics of the habitat. This study has to take into account the source–path–receiver model along with the detailed propagation properties of the tropical littoral settings of the IOR.

5. Underwater domain awareness

Maritime activities having a direct bearing on economic growth have to be assessed and their impact on the acoustic habitat has to be ascertained. Such inputs will be critical for the future management of undersea resources and activities for a sustainable model. Enhanced underwater domain awareness is essential for any calibrated approach, but will require massive infrastructure for continuous monitoring. Technology for such monitoring mechanisms undersea will present significant challenges in terms of operations, power supply, data transfer and maintenance.

6. Public awareness

A long-term vision with strong political will is required for a sustainable programme, and involving academia at all levels will be very critical for the success of such initiatives.

7. International agreement

No single nation can sustain the resources and infrastructure required for such a massive drive, and the transborder nature of pollution calls for efforts at a global level. Regional agreements among nations and, more specifically, a global regulatory framework and monitoring mechanism, keeping in mind the larger good, and site-specific undersea conditions have to be debated and finalised.

8. Economic growth versus environmental concern

The “end versus path” is a very relevant debate. A complete ban on maritime activities cannot be the solution, particularly for developing economies with livelihoods dependent on these activities for basic needs and survival. The socioeconomic factors would render such laws redundant and unimplementable. A calibrated approach with a sustainable growth using high-end technology solutions and precise underwater domain awareness will have to be evolved.

## Conclusion

Anthropogenic noise and its impact on the marine ecosystem is a known concern; however, effective regulations and monitoring mechanisms have yet to be put into a formal framework with statutory provisions. The IOR, due to its tropical littoral waters, has unique challenges in terms of underwater acoustic signal behaviour and propagation characteristics. The heightened maritime activities in the IOR associated with geo-strategic considerations have further elevated the urgency. The way ahead is complicated and long drawn. However, steps are required to arrest the steady degradation of the marine ecosystem due to higher levels of noise. A calibrated approach with an effective regulatory framework and monitoring mechanism can, however, promote a sustainable economic growth model.

## Notes

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