# The Impact of Ocean Noise Pollution on Marine Biodiversity

by

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Abstract

Most marine animals, particularly marine mammals and fish, are very sensitive to sound. Noise can travel long distances underwater, blanketing large areas, and potentially preventing marine animals from hearing their prey or predators, finding their way, or connecting with mates, group members, or their young. Decreased species diversity in whales and dolphins was related to an increase in seismic noise. Naval sonar has killed individuals and perhaps even genetically-isolated local populations of whales. Invertebrates such as lobster, crab, and shrimp, also show noise impacts. Noise has deafened fish, produced dramatically reduced catch rates, caused stress responses, and interfered with fish communication, schooling, and possibly the selection of suitable habitat. Whales have moved from their feeding and breeding grounds, shown stress, and foraged less efficiently due to noise. Noise has been thought to contribute to several whale species' population declines or lack of recovery. Many (at least 55) marine species have been shown to be impacted by ocean noise pollution to some degree. Thus, marine biodiversity is likely compromised by undersea anthropogenic noise. Noise levels are steadily rising, so ocean noise must be managed both nationally and internationally in a precautionary way before irreversible damage to biodiversity and the marine ecosystem occurs.

## Introduction

Most marine animals, particularly marine mammals and fish, are very sensitive to sound, using sound for almost all important aspects of their life including reproduction, feeding, avoiding hazards like predators, and navigation (Tyack and Miller 2002; Popper 2003). Sound can travel long distances underwater, sometimes hundreds or even thousands of kilometers, whereas vision is only useful for tens of meters underwater. Therefore, it is not surprising that much marine life uses sound as its principal sense.

Unwanted sound, or noise, can have a large impact on the marine environment, because noise can blanket a very large area, potentially preventing fish or whales from hearing their prey or predators, finding their way, or connecting with mates, group members, or their young. The U.S. Navy's Low Frequency Active Sonar, used to detect submarines, could affect marine life over an area of about

3.9 million square kilometers (Johnson 2003). This figure is based on levels shown to produce avoidance in fish and whales. Seismic airgun noise from oil and gas exploration measured 3,000 km away was the loudest part of the background noise heard underwater (Nieukirk et al. 2004). In some areas, underwater background noise levels have doubled every decade for the last several decades, most likely due to commercial shipping (Andrew et al. 2002; McDonald et al. 2006).

Though studies have been conducted on the impacts of ocean noise on various marine species, there have been no studies on the ecosystem-wide effects of noise. While any considerable novel addition to an ecosystem (like noise) can be expected to have an impact, one could argue that, because the oceans are naturally noisy environments (wave noise, rainfall, lightning strikes on water, etc.), marine animals would be adapted to noise. However, such adaptations would only be expected to be for natural noise sources commonly encountered over evolutionary time. The same would probably not apply to anthropogenic (human-made) underwater noise, which is a relatively recent addition to the marine environment. Especially for long-lived species, such as whales, and where human-made background noise levels are rapidly rising, animals are not likely to be able "keep pace" and genetically adapt at a rate similar to that of the change in habitat (Rabin and Greene 2002).

The impact of noise on marine genetic resources (MGR) is also unknown, though if there is a pattern of many marine species being negatively affected by noise, it follows that MGR will be compromised. The following studies are examples of such impacts.

## Impacts of Ocean Noise on Marine Animals

The only study I am aware of which related species diversity to ocean noise suggested a decline in cetacean (whale and dolphin) species diversity with an increase in the intensity of seismic survey activity (Parente et al. 2007). There was no significant change in oceanographic conditions measured, and survey effort for cetaceans was constant during this period, supporting the conclusion that the decline in diversity was due to noise. Moreover, there was an increase in the number of species found in nearby areas not exposed to intense seismic noise. It seemed as if transient species of dolphins moved out, accounting for the decreased species diversity.

Noise in the form of naval sonar or seismic surveys can be deadly to cetaceans in at least some cases. Whales have been found to die within hours, by stranding or deaths at sea, from even a transient and relatively brief exposure to moderate levels of mid-frequency military sonar (Fernández et al. 2005; NOAA and U.S. Department of the Navy 2001). Since 1960, when more powerful sonars emerged, more than 40 mass strandings of Cuvier's beaked whale have been reported world-wide. About 28 of these occurred together with naval maneuvers involving sonar or near naval bases, or with seismic surveys. In contrast, from 1914 to 1960, there was only one mass stranding reported of this species. Whales appear to die from hemorrhaging in their brain and heart, perhaps as a result of decompression sickness from an altered dive pattern induced by a panic response to the noise.

This family of whales known as the beaked whales seems particularly sensitive to noise. Beaked whales are also found in small, resident populations that appear to be genetically isolated (Dalebout et al. 2005). In one well-studied beaked whale population, there was a noticeable decline in numbers for years after a sonar-induced stranding, implying that much or most of the local population was either displaced or killed (Claridge 2006). Especially if local populations of beaked whales are indeed genetically isolated as is thought, such effects would cause a decline in MGR.

Even giant squid have apparently mass stranded due to seismic air guns (Guerra et al. 2004). A total of 9 stranded in 2001 and 2003. All suffered internal injuries, some severe, with internal organs damaged. Other invertebrates have exhibited good hearing ability. Prawn are as sensitive to sound as many fish, requiring that invertebrates be considered when evaluating the potential impacts of ocean noise on the marine ecosystem (Lovell et al. 2005). Brown shrimp reared in tanks had a higher metabolic rate under noise conditions, leading to a reduction in growth and reproduction over three months (Lagardère 1982). Snow crabs exhibited bruised organs and abnormal ovaries, smaller larvae, delayed development, soiled gills, and signs of stress in response to seismic noise (Department of Fisheries and Oceans 2004). There were indications that lobster showed increased food consumption and histochemical changes for weeks to months after low-level exposure to seismic noise. Codfish also showed increased food consumption for more than a month following seismic noise exposure, as well as an alteration of gene expression in the brains of the exposed cod.

Other sub-lethal effects have also been documented. These may be as serious as lethal impacts because they may affect more animals yet be harder to detect. Seismic air guns have been shown to extensively damage fish ears at distances of 500 m to several kilometers (McCauley et al. 2003). Reduced catch rates of 40-80% and fewer fish near seismic surveys have been reported for cod, haddock, rockfish, herring, sand eel, and blue whiting (e.g. Engås et al. 1996; Skalski et al. 1992, Slotte et al. 2004). Only moderate levels of noise have been enough to cause temporary hearing damage in some species of fish, with fish occasionally requiring weeks to recover their hearing (Scholik and Yan 2002; Amoser and Ladich 2003). Noise has also been shown to produce a stress response in some fish. Wysocki et al. (2006) found that all three fish species studied secreted stress hormones in the presence of shipping noise, regardless of the species' hearing sensitivity (whether it was a hearing specialist or not). Fish can also react to noise by dropping to deeper depths, becoming motionless, becoming more active, or forming more compact schools. Ship noise interfered with the ability of toadfish to detect sound in a river estuary, which could affect communication necessary for reproduction (Vasconcelos et al. 2007). Bluefin tuna showed a disruption in their schooling structure and swimming behavior with boat noise, as well as an increase in aggressive behavior (Sarà et al. 2007). As coordinated schooling helps tuna to home more accurately to spawning and feeding grounds, their migrations could be impacted. Reef fish, at the critical settlement stage, need to be able to hear aspects of reef noise to select suitable habitat (Simpson et al. 2008). Anthropogenic noise that interferes with their "soundscape" could impact their natural behavior.

To show how early fish can become sensitive to noise, the heart rates of embryonic clownfish were found to increase significantly with noise exposure (Simpson et al. 2005). Embryos as young as 3 days after fertilization exhibited this response. As embryos developed, their sensitivity to noise and to a broader spectrum of noise increased, up to the point of hatching. Not having symmetrical ear structures seems to hinder reef fish larvae from localizing sound well (Gagliano et al. 2008). These larvae had a more difficult time finding suitable settlement habitat and likely suffered increased mortality as a result. Thus, the addition of anthropogenic underwater noise would probably further impact the survival of these fish. Different groups of trout from the same supplier varied in how they reacted to the same noise, suggesting there is a developmental or genetic component in sound sensitivity (Popper et al. 2007). Thus, preserving genetic diversity seems important in ensuring that enough individuals with good hearing ability are produced.

Whales have moved away from their feeding and breeding grounds (e.g. Bryant et al. 1984; Morton and Symonds 2002), have altered their migration route (e.g. Richardson et al. 1995) and have changed their calls (Lesage et al. 1999) or fallen silent due to noise (Watkins and Schevill 1975). They have blundered into fishing nets (Todd et al. 1996) or were unable to avoid ships most likely due to hearing damage as a result of noise. There were indications of increased stress and a weakened immune system following noise broadcasts in a captive whale (Romano et al. 2004). A Cuvier's beaked whale exhibited an estimated decrease of >50% foraging efficiency during a noise-exposed dive compared with other dives of the same animal (Aguilar Soto et al. 2006). Masking, or the interference of signals due to noise, can cause animals to miss hearing the sometimes very faint sounds of their prey or predators, mates, group members, or navigational cues. Obviously, this can have survival consequences. Noise has been thought to contribute to several whale species' population declines or lack of recovery.

Many marine species have been shown to be impacted by ocean noise to some degree. A cursory review of the literature on noise impacts revealed that at least 55 marine species have exhibited impacts from underwater noise in scientific studies. These impacts are not from nearby explosions, but more moderate noise. In cetaceans, the following 24 species have responded negatively to ocean noise: sperm whale, gray whale, bowhead whale, humpback whale, minke whale, Northern right whale, pygmy sperm whale, dwarf sperm whale, pilot whale, melon-headed whale, killer whale, beluga whale, Cuvier's beaked whale, Blainville's beaked whale, Gervais' beaked whale, bottlenose whale, Risso's dolphin, common dolphin, bottlenose dolphin, humpback dolphin, white-beaked dolphin, white-sided dolphin, Dall's porpoise, and harbor porpoise. At least 3 seal species have reacted negatively to underwater noise: elephant seal, gray seal, and harbor seal. In fish, the following 21 species have shown impacts to noise: pink snapper, goldfish, cod, haddock, rockfish, herring, sand eel, blue whiting, catfish, sea bass, thicklip mullet, horse mackerel, bluefin tuna, fathead minnow, toadfish, carp, gudgeon, perch, silver bream, trumpeter, and trevally. At least 5 invertebrate species (squid, giant squid, snow crab, lobster, and brown shrimp) and 2 marine turtle species (loggerhead turtle and green turtle) have shown negative responses to noise. Thus, it is hardly plausible that underwater noise would not affect marine biodiversity to some degree. Noise is listed as an intrusion and one of the impacts that can result in a substantial loss of biodiversity over time in sensitive marine habitats (Warner 2008).

The impacts of noise can work cumulatively or synergistically with other environmental threats to cause, for instance, more by-catch (net entanglements) or ship strikes due to a failure to detect fishing gear or hear oncoming ships. Already food-stressed animals, e.g. from chemical pollution or overfishing, may be unable to hear their prey because of anthropogenic ocean noise. Many different noise sources can also cause a magnified effect that may be greater than the sum of the individual noise sources, such as when seismic noise is superimposed on shipping noise.

## Conclusion

Thus, underwater noise is clearly a serious issue for marine species, although the full scale of the problem is difficult to determine. There are practically no studies on the impacts of ocean noise pollution on marine biodiversity. To my knowledge, the FAO and its specialized Agencies have not conducted such studies. I would regard the technical expertise of FAO, and its Fisheries and Aquaculture Department in particular, as needed in carrying out evaluations on the socioeconomic impacts of underwater noise on fishing catch rates. This could be a starting point because, generally speaking, there is significant scope to study negative impacts of underwater noise on marine biodiversity. Noise levels are steadily rising, so ocean noise must be managed both nationally and internationally before irreversible damage to biodiversity and the marine ecosystem occurs. In light of the data gaps, I would recommend a precautionary approach in the management of undersea noise.

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