How does anthropogenic ocean noise affect marine life?

Introduction

New research strongly indicates that anthropogenic ocean noise harms marine life [8]. Anthropogenic ocean noise is underwater noise pollution created by humans. Global shipping, military sonar, and seismic blasts disrupt the underwater communication of marine animals [6]. Many human activities such as trade and shipping, naval exercises, and oil exploration cause these sound waves [3]. Communication is a key aspect of surviving in the ocean. Hearing is the most important sense for marine animals, and they use it for almost everything they do. Marine animals need to communicate in order to find food, breed, establish social structure, and avoid predators [3]. When their only means of communication is blocked by ships, sonar, or seismic waves, marine animals cannot do any of these things. More directly, these human generated sound waves can cause permanent or temporary deafness, stress and disorientation, and can force marine animals out of their preferred habitat [3]. Recent findings show that the number of strandings have increased. The increase in anthropogenic ocean noise can be linked to this, as well as many other deaths in marine animals [1]. This extreme noise pollution affects most marine animals, especially humpback whales [6].

Research questions:

- What underwater locations are likely to have harmful levels of anthropogenic noise?
- What marine animals are affected?

Hypothesis:

- I hypothesize that certain endangered marine animals will have habitats that are near areas with a high concentration of shipping. As a result, these endangered animals will likely be exposed to high levels of anthropogenic ocean noise.

Methods

In this project, I created a map and two graphs showing relationships between global shipping and marine mammals' living environments. I used publicly available data to create a map in QGIS that shows overlap between global shipping and certain marine life. I used "Global Ship Density" from "Global Shipping Traffic Density" to create this map. "Global Shipping Traffic Density" is from the World Bank, and is a data set of shipping routes worldwide [2]. The data set was constructed based on shipping data collected from 2015-2020. I used this data to make a map in QGIS that I would be able to edit and layer. It was challenging to find data on dolphin and humpback whale habitats, because I needed exact coordinates (latitude and longitude) in order to layer them on my map of shipping routes. Many data sets did not have latitude and longitudes for these marine animals. Because of this, the only data I was able to layer on the map of shipping routes with exact locations was located in the Indian Ocean. This data set for the Indian Ocean is called "Happywhale - Humpback Whale in Indian Ocean", from OBIS-SEAMAP at Duke University [5]. Another challenging aspect in finding data is that most of the data on whales and dolphins are sightings from land. This makes it hard to find out where in the ocean the highest concentrations of dolphins and humpback whales are. So, I made a rough sketch of where each group of humpback whales generally lives in the ocean on the map, along with their population status. I based these sketches on data from NOAA Fisheries [3]. I also included a general idea of breeding and feeding grounds for humpback whales (NOAA) [3]. I made sketches of the groups of humpback whales and the feeding and breeding grounds using Toggle Editing in QGIS.

Another idea that was important to explore was how the hearing ranges of certain marine animals overlapped with the frequencies of sound waves emitted by ships. I made two graphs using Excel that illustrate the overlap between hearing ranges of marine animals and the sound waves generated by ships. The first graph (Cetacean Hearing Ranges and Sensitivity) shows the hearing ranges and points of sensitivity of humpback whales, bottlenose dolphins, and harbor porpoises (in Hertz) [9]. It also shows the range of frequencies in the sound waves generated by ships. The second graph (Overlap Between Humpback Whale Hearing Range and Ship Soundwaves) shows specifically the overlap between shipping generated sound waves and the hearing range and sensitivity of humpback whales. I used data from “Hearing Sensitivity Studies” from “Discovery of Sound in the Sea” [10] and “Relationship between container ship underwater noise levels and ship design, operational and oceanographic conditions” from “nature.com” [4] to create these graphs. I also researched the ears and hearing systems of the toothed and baleen whales [7]. I analyzed a CT scan of an Atlantic white-sided dolphin from “Hearing in Cetaceans and Sirenians, the Fully Aquatic Ear” from “Discovery of Sound in the Sea” [10]. The CT scan, map of shipping routes, and both graphs were important to analyze and interpret in order to fully understand the effects of ocean noise pollution.

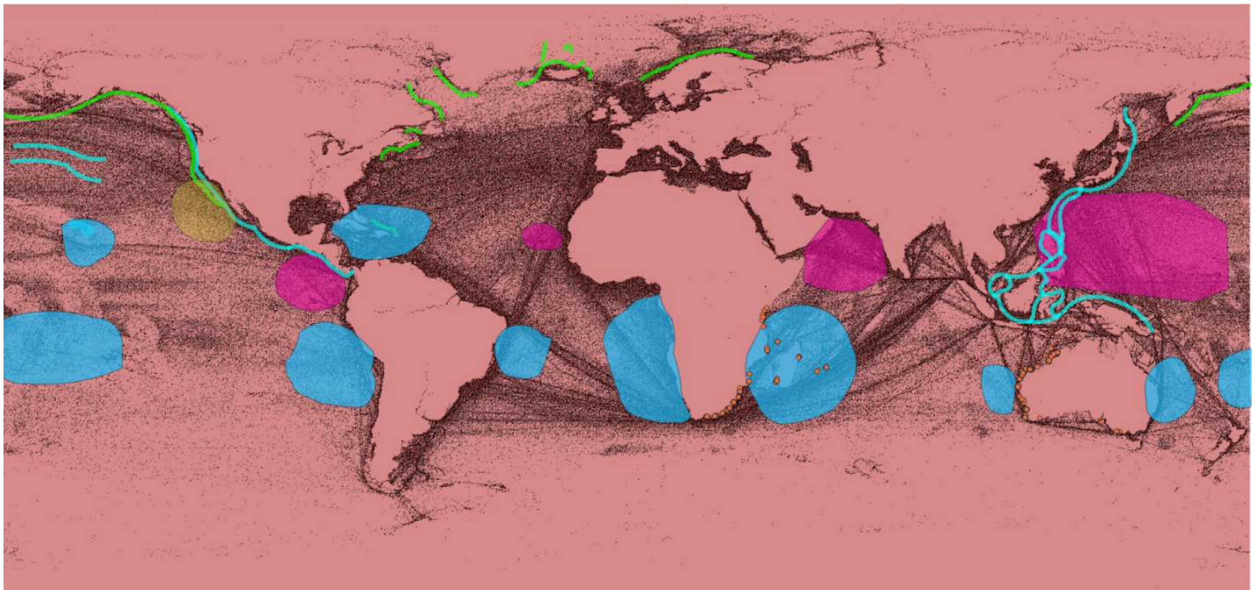
Results

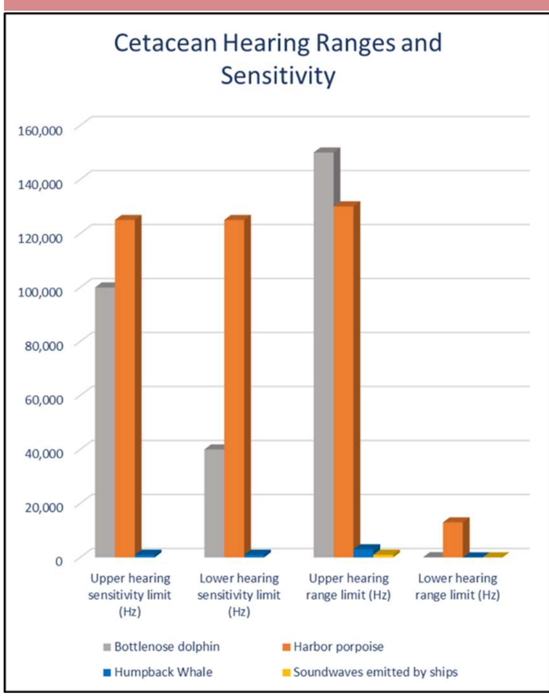
The map of global shipping showed that there are many areas of overlap between whale habitats and shipping routes. Many breeding grounds are also near places with heavy shipping. However, most humpback whale feeding grounds are not in places with a high concentration of shipping. The endangered and threatened whale groups are all in areas with a relatively high concentration of ships. The whale groups that are not at risk have mixed results regarding how heavy shipping is in their area. Not at risk groups on the far east and far west side of the map are in areas with low ship concentration. However, not at risk groups towards the middle of the map are in areas with average to heavy shipping.

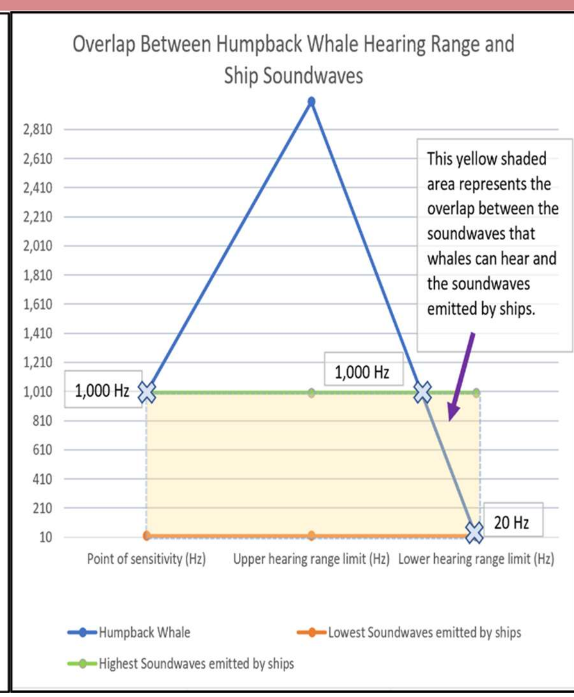
The first graph that I made (Cetacean Hearing Ranges and Sensitivity) showed that the hearing range of harbor porpoises is too high for them to be able to hear shipping sound waves. The lower limit of porpoise hearing is 12,000 Hz higher than the highest soundwave generated by ships. This graph also showed that the lower limit of bottlenose dolphin sensitivity is 39,000 Hz higher than the highest noise emitted by ships. Finally, this graph showed that the hearing range of the humpback whale and the range of sound waves generated by ships are very similar.

The second graph (Overlap Between Humpback Whale Hearing Range and Ship Soundwaves) illustrates what frequencies of sound waves that both ships emit and that humpback whales can hear. There is 980 Hz of sound that both ships generate and humpback whales can hear (both of their ranges include frequencies from 20 Hz to 1,000 Hz). This graph also shows that the humpback’s most sensitive point in its hearing (1,000 Hz) is included in the range of ship sound waves.

The results of my research on the anatomy of the toothed and baleen whale were that the hearing ranges of toothed and baleen whales depends on two things: the way they transmit sound to the Tympanoperiotic complex (TPC) and the characteristics of their basilar membranes. The results from my research, map, and graphs helped me understand relationships between shipping and cetaceans.







Discussion

Endangered and threatened groups of whales are all in areas with heavy shipping. This supports my hypothesis. Although there are other factors about the ships that pose a threat to these whales (collisions with ships, oil leaks from ships, etc.), noise from ships is also a factor. However, it is important to consider the results of the not at risk groups, because they did not support my hypothesis. Some not at risk groups are located in areas with relatively heavy shipping. So, some other factor may have more impact on whales than shipping and ocean noise.

High levels of shipping near breeding grounds could be detrimental to populations of humpback whales. Communication is a key aspect in breeding and mating for humpback whales, and almost all whale songs are produced on breeding grounds. Male whales sing to female whales as a breeding display. They also need to communicate to other whales on the breeding grounds to establish territory, or claim space in the breeding grounds [10]. With so much noise caused by ship cavitation, the whales' songs and attempts in communication are lost. Based on this analysis, I predict that there will be a decrease in both whale calves and whale songs as shipping increases over time.

Most humpback whale feeding areas are in northern, more remote areas. Because of this, there are relatively low levels of shipping in feeding grounds for humpback whales. For humpback whales, sound is vital for foraging food. Humpbacks use feeding calls to startle their prey and to collaborate with their hunting partners [10]. Luckily, shipping does not affect humpback whale feeding.

The hearing ranges of harbor porpoises, bottlenose dolphins, and humpback whales was very important to consider in this project. Porpoises are not affected by sound waves from shipping, because the sound waves are too low for them to hear. They are the least affected out of humpback whales and dolphins by these shipping sound waves. Although dolphins are able to hear shipping sound waves, their range of sensitivity is much higher than the frequency of ship generated sound waves. So, the dolphin would not be the most affected animal by shipping noise, but definitely more affected than the harbor porpoise. Lastly, the humpback whale hearing range and the range of sound emitted by ships have a great area of overlap. Humpbacks have a lower, more limited range, much like the sound waves from ships. Therefore, the humpback whale would be most affected by shipping noise.

These differences in hearing ranges across humpback whales, dolphins, and porpoises led me to investigate the reasons for these differences. Humpback whales are baleen whales, and dolphins and porpoises are toothed whales. Toothed whales and baleen whales have different ways of receiving sound and transmitting it to their Tympanoperiotic complex (TPC). The TPC is a cluster of ear bones connected to the skull, and it contains the cochlea [7]. This difference in receiving sound results in their different hearing ranges. Baleen whales have two different ways of receiving sound. One way is to receive sound waves through the soft tissue on their face and jaw. This version of sound comes into the soft tissue and fat through pressure waves. This method of transmitting sound to the TPC only receives sound waves with shorter wavelengths, meaning higher frequencies. The second way baleen whales receive sound waves is through their skull. The sound waves come in contact with the hard, bony skull, causing vibrations within the skull. These vibrations cause the skull to amplify the sound it receives. This method of transmitting sound to the TPC is used for sound waves with much longer wavelengths, meaning much lower frequencies. This method is much more effective to transmit sound to the whale ear, because it amplifies it and makes it easier to hear [7]. This explains why the humpback whale is more sensitive to lower sounds, because the lower sounds are the ones that are made easiest to hear.

The toothed whales (dolphins and porpoises) only use the first way of receiving sound that baleens use. This method is more appropriate for dolphins and porpoises, because they have cavities of fat under their jaw [10]. They have much more fat and soft tissue on their face than baleen whales.

Another factor that contributes to the difference in hearing ranges between baleen whales and toothed whales is a part of their ear called the basilar membrane. The basilar membrane is in the cochlea. The stiffness and thickness of the basilar membrane results in the difference in hearing ranges between baleen and toothed whales. Toothed whales have a very stiff and thick basilar membrane. This is one reason that they have a high hearing range. However, baleen whales have a thin, elastic basilar membrane, resulting in a low hearing range [10]. All of these findings about cetaceans, hearing, and shipping were important to this project.

Conclusion

I can conclude that out of dolphins, porpoises, and humpback whales, humpback whales are the most affected by shipping noise. The anatomy of the humpback whale face and ear causes it to have a low sensitivity and hearing range. This causes the humpback whale hearing range to share a large area of overlap with shipping sound waves. Many humpback whale breeding grounds are in areas with heavy shipping, which is not good for the future population of humpback whales.

It is important to study the causes and effects of anthropogenic ocean noise. This noise is harming many marine mammals, especially humpback whales. Anthropogenic ocean noise threatens humpback whale habitats and breeding grounds, along with the population, health, and wellbeing of the humpback whale.

Citations

Works Cited

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