The impact of bottom trawling fisheries on marine mammals - A review

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Abstract

Bottom trawling is an important way of industrial scale fishing, being responsible for a large part of total fishery landings. However, it is also a very damaging way of fishing. One group of animals on which the effects of bottom trawling has not been studied very extensively, is marine mammals. To research these effects, the following research question is answered: “In what ways are marine mammals affected by bottom trawling fisheries?” Marine mammal bycatch in bottom trawling nets is a threat to populations, and solutions to lessen marine mammal bycatch often do not help and can even be harmful, so should be considered carefully. Noise pollution from bottom trawling can damage marine mammal auditory systems and change their behaviour and vocalisation. Target species overlap between bottom trawling fisheries and marine mammals is highest with marine mammals preying on benthic species, and bycatch influences prey abundance for other marine mammals. Behavioural effects happen due to exposure to noise, causing cetaceans to change vocalisations. Marine mammals also change their feeding behaviour and even social structures and behaviours when in proximity to trawlers. It is clear that marine mammals are impacted in different ways by bottom trawling fisheries. Seemingly foremost of these impacts is the behavioural impact, but also one of the less researched impacts. Future research should focus more on the behavioural impact of bottom trawling fisheries on marine mammals.

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Introduction

Ocean ecosystems provide a wide variety of services to humans. One of the most important services is the food and resources taken from these ecosystems, as well as providing a major carbon sink, fixing 25% of our carbon emissions and generating 50% of the oxygen in the air (Sumaila et al. 2016). We extract food and resources from oceans with industrial scale fisheries, often with large international fleets with many operational fishing vessels (European Commission, 2018). Through these industrial scale fisheries, many people can be fed. However, they are also very damaging to ocean ecosystem health, depleting and overfishing many fish stocks, causing ripples through the food web. One of the biggest ways of industrial scale fishing is bottom trawling. Bottom trawling also makes up for around 25% of all fishery landings, equating to about 19 million tonnes of fish annually, which means that bottom trawling feeds billions of people and generates many jobs, both directly and indirectly (Kaiser et al. 2019). Dragging a net through the ocean floor is an incredibly intensive and impactful way of fishing, as one pass of a trawling net can reduce benthic species abundance by 26% and species diversity by 19% (Sciberras et al. 2018). This way of fishing consists of boats pulling a large net over the ocean floor to catch animals living on or in it. This can be done in multiple ways, which all vary in the type of net used, and also how deep and intensively the seafloor is trawled. The extent and frequency at which the seabed is trawled differs globally, but in some areas in Europe, on the North Atlantic seabed, more than 50% of the seabed is trawled annually (Amoroso et al. 2018). Kelleher (2004) reported that trawling fisheries make up 50% of global fishery discards, meaning that alongside the large number of landings, many caught fish are also thrown overboard, often dying or already dead.

One group of animals that might still be impacted by bottom trawling fisheries are the marine mammals, even though they are not directly targeted by these fisheries. This group of animals consists of 126 extant species in 3 different orders Cetartiodactyla, which is the order of whales (but also deer and cattle), Sirenia, the order consisting of manatees and dugongs, and Carnivora, the order of pinnipeds, sea otters and even the polar bear is often counted as a marine mammal (Nowak, 2003). They are often higher in the food chain and can be found around the globe. Marine mammals are often considered to be charismatic species, which often makes them flagship species for conservation projects. Marine mammals, especially cetaceans like whales and dolphins, have traditionally been the target species for hunting by indigenous people, and more recently also the target of large scale commercial whaling industries. This led to the extinction of some marine mammal species, like the Steller's sea cow (*Hydrodamalis gigas*), and the endangerment of others, as around 25% of marine mammals are on the IUCN Red List (Nelms et al. 2021). They are not only threatened by being the target of whaling, but also indirect effects, like habitat degradation, noise pollution by sonars and shipping vessels, and even as bycatch by fisheries.

The aforementioned threatening effects to marine mammals might also give some insight into how they might be impacted by the bottom trawling industry. Which also leads to the research question: "In what ways are marine mammals affected by bottom trawling fisheries?"

To help answer this question, multiple different impacts related to bottom trawling fisheries will be researched and discussed in the form of sub-questions:

- “How are marine mammal populations affected as bycatch of bottom trawling fisheries?” Hypothesis: Marine mammal bycatch in bottom trawling nets might have an effect on marine mammal population if it leads to high mortality.
- “What effect does noise pollution from bottom trawling have on marine mammals?” Hypothesis: Noise pollution from trawling the seabed might damage marine mammal auditory organs, which in turn might cause strandings.
- “How extensive is the trophic overlap between bottom trawling fisheries and marine mammals?” Hypothesis: Trophic overlap between marine mammals and bottom trawling fisheries might cause food-web disturbances.
- “How are marine mammals affected behaviourally by bottom trawling vessels?” Hypothesis: Marine mammals are likely affected in different ways, like changing feeding behaviour, vocalisation behaviour and migratory behaviour.

This paper aims to answer the research question using information and articles found on the Web of Science database, from researchers that have already done research on the impact of bottom trawling or other fisheries on (a subset of) marine mammals. It is likely that bottom trawling affects marine mammals in all of the ways mentioned above, to some extent.

Research findings

Here, studies and papers from Web of Science will be examined and summarised to make conclusions about the effects of bottom trawling on marine mammals. Research on marine mammal-bottom trawling interactions will be used, but also research on marine mammal interactions with other large-scale maritime industries, like pelagic fisheries and shipping vessels. To present the information in a clear way, each sub-question mentioned in the introduction will be answered separately.

Marine mammals as bycatch

A very direct impact of bottom trawling, and fishing industries in general, is the entanglement or bycatch of marine mammals. Entanglement in nets often leads to mortality of or sever injuries to the entangled animal (Meyer et al. 2017). To effectively examine the impacts of bycatch, the overarching question to be answered in this part of the review is: “How are marine mammal populations affected as bycatch of bottom trawling fisheries?”.

One study done by Morizur et al. (1999) looked into marine mammal bycatch occurrences in the North Atlantic. 1771 hours of towing were observed in four different countries’ fisheries. In those hours of towing, 18 dolphins were caught by Dutch and French fisheries, and 4 grey seals were entangled in Irish nets. A seemingly small number, this translated into a bycatch rate of all marine mammals in 1 out of 17 tows, or 1 per 80.6h of towing. When this is combined with the enormous amount of hours that are spent trawling the ocean floor and the size of the European fishing fleet, this can mean a biologically significant amount of marine mammal bycatch, to the point that certain populations of marine mammals could start significantly decreasing in numbers. Another important observation in this study was also made when researchers observed both dolphins and seals feeding from nets filled with fish, and stomach contents of dead entangled individuals also revealed that they had fed on the target species of the trawl fisheries. A danger here is shown as well, that these trawl nets might encourage close proximity of marine mammals. This also ties into the behavioural disturbances caused by bottom trawling, which will be discussed more in depth below. In a different study, Lewison et al. (2014) made a comprehensive analysis of global megafauna bycatch data, and mapped it. Most marine megafauna species studied in this research were cetaceans. By doing the megafauna bycatch analysis, they were both able to find that megafauna bycatch by bottom trawling is the least intense, but also that bycatch is a cumulative effect over gears used by fishing boats and over taxa of marine megafauna. Because so many species in that group are wide-ranging and travel long distances, they come into contact with many different types of fisheries using different types of gear. This makes any species- or gear-specific management plans difficult to make, and traditional management and mitigation efforts against bycatch might not be effective in the conservation of marine mammal populations.

There are solutions in place to avoid marine mammals, and other animals like turtles, getting entangled in nets. This is done via exclusion devices, where nets are altered or additional parts are installed to direct non-target species outside the net (Cox et al. 2007). However, these devices are often not perfect, and could even be harmful. A study done by Cox et al. (2007) studied the efficacy of exclusion devices for marine mammals and turtles. In the Gulf of Maine,

4% of the harbour porpoise (*Phocoena phocoena)* population died annually in gill nets, which led to the development of pingers. These pingers warned animals, leading to a 50-80% reduction in porpoise bycatch. After some years, however, the porpoise bycatch started to rise again. This could then be traced back to non-compliance by fishers, with a 78% rate of non-compliance, employing nets without alarms. This shows that even though exclusion devices can help marine mammal populations, these devices need to be complied with, and rules about these devices need to be enforced much better. Another study done by Meyer et al. (2017) actually found that exclusion devices could be harming the New Zealand sea lions (*Phocarctos hookeri*), instead of helping them, as they should be doing. Their analysis on the effectiveness of exclusion devices found that they could be contributing to the endangerment of sea lion populations, by concealing mortality and reproductive failures, especially post-release, caused by bycatch in nets. These concealed losses also in turn cause a less effective management of sea lion populations.
The research shown here illustrates the threat incidental bycatch of marine mammals by bottom trawling poses to their populations. It also shows that measurements to avoid this should be carefully considered and properly enforced, and that conservation plans need to take into account the wide-ranging and migratory nature of many marine mammals.

The effects of noise pollution from bottom trawling

A different, but still direct, way that bottom trawling might impact marine mammals is through noise pollution. In this part of the review, the effects of exposure to noise pollution from bottom trawling vessels will be examined and the following question answered: “What effect does noise pollution from bottom trawling have on marine mammals?”
This is one of the times where the generalisation of marine mammals as one group might be problematic. According to examinations done by Au et al. (2008), marine mammal auditory systems are quite different from one another. Pinniped and sirenian auditory systems resemble the auditory systems of terrestrial creatures, while those of cetaceans are more adapted to their marine environments. It also becomes clear that especially cetaceans highly rely on sound and echolocation to hunt, communicate and move around. If these auditory systems are damaged in cetaceans, by exposure to loud noises, it can lead to strandings. This was found when Wang et al. (2021) examined strandings of melon headed whales (*Peponocephala electra*) on the east coast of China, and found that the stranded whales exhibited hearing loss, but were unable to conclude if the hearing loss was due to exposure to loud transient noise like a military sonar, or due to chronic noise exposure from commercial shipping vessels. It was however clear that the strandings could be directly linked to hearing loss in these cetaceans, and that the hearing loss was caused by anthropogenic factors. This could be significant if bottom trawling fisheries generated a lot of noise.
This is the study done by Daly et al. (2021), who looked into the noise generated by bottom trawling fishing vessels, is relevant here. They found that trawling the seabed generated a significant amount of noise, enough to likely be directly damaging to the auditory systems of some cetaceans. However, the damaging levels of noise were quite close to the net, and became less damaging at a greater distance. There are still considerations to this, as chronic exposure to loud noise could still damage marine mammals' auditory systems, and also have

effects on their behaviour. The behavioural impacts of noise pollution on marine mammals will be expanded upon in a lower section.
To illustrate the effects of prolonged noise exposure, a different review done by Erbe et al. (2019) looked into the effects of chronic shipping noise on the different groups of marine mammals. It becomes quite evident that marine mammals are differently affected by chronic exposure to noise from ships, even marine mammals within the same group. For example, grey whales (*Eschrichtius robustus*) increase vocalisation rate and levels when in proximity to ships, while humpback whales (*Megaptera novaeangliae*) increase vocalisation levels but not rate, and Northern Atlantic right whales (*Eubalaena glacialis*) showed no behavioural changes at all when a ship passed by in close proximity. Sirenians, especially the manatee (*Trichechus* spp.), showed a lack of avoidance of boats, even though they should be sensitive to the noise generated by them. Pinnipeds also showed behavioural changes when ships passed by, like moving away from the ship or altering communication.
It is evident from research that marine mammals can both receive damage to their auditor systems and alter behaviour and vocalisations from chronic noise generated by bottom trawling and bottom trawling shipping vessels.

Trophic overlap between marine mammals and bottom trawling fishing vessels

As mentioned in the introduction, marine mammals are often high up in the food chain, relying on smaller taxa as a source of food. However, most marine mammals are pelagic, living in the water column and close to the surface, in turn also relying on pelagic prey (Machado et al. 2020), while bottom trawling mostly targets benthic or demersal species, like shellfish, shrimp and flatfish. Some marine mammals do not rely on fish at all, like filter feeding cetaceans relying on zooplankton and krill or sirenians grazing on seagrass, and the impact of prey depletion from bottom trawling, or any fisheries, would be minimal. From this, one might take away that the trophic overlap between bottom trawling and marine mammals is small, especially when compared to pelagic fisheries. To thoroughly examine the effects of this trophic overlap, the following question will be answered: “How extensive is the trophic overlap between bottom trawling fisheries and marine mammals?”
Examinations of 5 marine mammal species in the South Atlantic (South American sea lion *Otaria flavescens*, fur seals *Arctocephalus australis*, franciscana dolphins *Pontoporia blainvillei*, bottlenose dolphins *Tursiops truncatus* and Lahille’s bottlenose dolphins *T. gephyreus*) were done by Machado et al. (2020), and the contents compared with the catch of local fisheries. The South American sea lion relied on mostly demersal prey, while the other marine mammal species relied on a wide range of prey, including demersal, benthic and demersal- and benthic-pelagic prey. In turn, they found that marine mammals with more benthic species in their diet had more trophic overlap with target species of bottom trawling fisheries. The examined species that showed the most overlap with bottom trawling were the South American sea lion and both bottlenose dolphin species. Another interesting finding was that, even though bottom trawling did not target the two most important prey species for the marine mammals (the fish *Paralonchurus brasiliensis* and *Trichiurus lepturus*) in the area that was studied, they did make up around 31% of discards, which impacts the prey populations, and in turn those of the marine

mammals even though there might not have been direct trophic overlap. Vales et al. (2013) found a similar result when studying the effect of fisheries on the diet of South American fur seals, that rely mostly on small pelagic fishes as prey, while local intensive fisheries mostly large demersal fishes. The result of the dietary examinations on the fur seals was in line with Machado's study, and the diet of the fur seal had not changed in the last 17 years, and likely would not if fisheries do not target the small pelagic fish that make up the seals prey.
It seems that the trophic overlap between marine mammals and bottom trawling target species is small, and does not impact the marine mammal populations much. However, because of the large amount of bycatch in bottom trawling nets, marine mammal prey populations are still impacted negatively, which in turn also negatively impacts the marine mammal populations.

Behavioural disturbances in marine mammals caused by bottom trawling

In answering the last three sub-questions, some behavioural disturbances were already discussed shortly, and will be examined in more detail here, along with other impacts of bottom trawling on marine mammals. The aim of this part will be to answer the question: "How are marine mammals affected behaviourally by bottom trawling vessels?"
The first behavioural disturbance caused by not only bottom trawling but other fisheries as well, is the occurrence of depredation. Before getting into detail about depredation, it is important the term should be defined as the act of foraging around and from fishing gear. This is done because a paper written by Bearzi et al. (2022) pointed out the negative connotations of the word depredation. Depredation is often used outside of marine biology studies to mean "to destroy", "to ransack" or "to plunder", while depredation in the marine context means "to forage in or around fishing gear". This means that one should carefully consider the use of the word depredation when writing about marine mammals and the conservation thereof.
The depredation behaviour of odontocete cetaceans near trawlers was also looked into by Bonizzoni et al. (2022). This depredation could happen in multiple ways, like entering the net to feed on prey, feeding on prey that was stirred up by the net, feeding on prey in the net from outside, feeding on lost catch and scavenging bycatch. There is also the act of 'secondary foraging', when an odontocete (or other marine mammal) feeds on a target that is interacting with a fishing vessel. This was observed when a group of killer whales hunted a group of pinnipeds scavenging from a trawler vessel. Even though depredation might increase food intake for marine mammals, lessen energy expenditure, and even lessen the effects of scarcity of prey due to intensive fishing, these benefits are offset by the negative effects of the close proximity to trawlers. There are the more direct effects of proximity, like exposure to pollutants from trawlers, both from the water and emissions in the air, exposure to noise from trawlers and incidental mortality, like getting entangled in nets or getting hit by the boat motor. Beside these direct effects, there are also more indirect behavioural effects. Chilvers et al. (2001) found that bottlenose dolphins actually formed two distinct social groups when trawling happened in proximity, "trawler" and "non-trawler" groups, where the "trawler" group would depredate trawlers, while the "non-trawler" group would avoid trawlers altogether. These two groups almost never associated with one another, despite living in the same location. However, when trawling was banned in the dolphins home range, the social partitioning dissolved, and the dolphins

started to associate with one another. This social divide that happens when trawlers are in proximity might be self-reinforcing, as dolphins learn and teach these feeding behaviours culturally (Donaldson et al. 2012).

Marine mammals are also often wide ranging and migratory, especially cetaceans, travelling many miles in their lives. Despite this large amount of travelling, migratory marine mammals also exhibit site fidelity, meaning that they return regularly to the same location (Lascelles et al. 2014). However, this site fidelity could be influenced by the activity of trawling on the sites migratory species return to. If prey abundance is reduced or excessive noise pollution is generated, marine mammals might alter their migration patterns to find more suitable habitats. The migratory behaviour of marine mammals also poses a challenge in their conservation and management, since a local ban or measure on trawling might not help their populations, as they can still be affected by trawling that happens at the locations local marine mammal populations migrate to. The proper conservation of migratory marine mammals should take this migratory behaviour into account, and measures that are taken for this conservation should often be international.

Marine mammals can be behaviourally affected in different ways by bottom trawling. They can change feeding behaviour and diets. They can alter social structures and behaviours when trawling happens in proximity, and migratory behaviour can also be affected.

Discussion

The impacts of bottom trawling can be divided into two groups, direct and indirect impacts. The answer to the question: “In what ways are marine mammals affected by bottom trawling fisheries?” lies in these two groups.

On the direct level of impacts, marine mammals can get entangled in trawling nets, often leading to mortality or severe damage, and these entanglements happen at a considerable rate in bottom trawling nets (Morizur et al. 1999). Marine mammal auditory systems can also get damaged when in prolonged proximity to bottom trawling vessels, especially when actively trawling. Damage to auditory systems can then lead to strandings in marine mammals, especially those that rely a lot on sound and echolocation (Wang et al. 2021, Erbe et al. 2019), which means cetaceans are directly impacted most by noise pollution. Marine mammals with a diet containing more benthic species will be impacted most by bottom trawling, because of a smaller prey abundance, but prey species for other marine mammals can also be caught as bycatch in bottom trawling nets (Machado et al. 2020).

Marine mammals can also be impacted indirectly by bottom trawling. These effects are mostly behavioural. Cetaceans often change their vocalisation levels and rates when in proximity to noise, while some pinnipeds either move away from ships or lessen their vocalisations (Erbe et al. 2019). Marine mammals also change feeding behaviour when in proximity to trawling vessels, choosing to depredate prey caught in trawling nets, or even hunting animals that are depredating. In bottlenose dolphins, this changing of feeding behaviour even reflects an alteration of social structure.

Research indicates clearly that there are considerable and significant effects of bottom trawling on marine mammals, both on the individual and population level. There are, however, also some holes or biases in the available data and research. The foremost of these biases is the type of marine mammals studied, both in context of bottom trawling but also in general. Cetaceans, especially three species of them, the bottlenose dolphin, the humpback whale and the beluga whale, are more often the attention of research into effects of large scale fisheries compared to other marine mammals, like pinnipeds and sirenians. For sirenians, one could argue that these do not share their ranges with these fisheries, often staying in shallower areas (Nowak, 2003), but pinnipeds most assuredly come into regular contact with bottom trawling vessels. Pinnipeds are also phylogenetically distant to cetaceans, and the way bottom trawling might affect cetaceans can differ for pinnipeds. This shows that it is important that more research is done on non-cetacean marine mammal groups, to ensure proper management in regards to non-cetacean marine mammal interactions with bottom trawling fisheries.

Another important gap in scientific literature is that there is a relatively small number of articles that examine the interactions between marine mammals and bottom trawling, especially when compared to other large scale pelagic fisheries, like gill-nets and longline fisheries. From research, it might seem that marine mammals interact less with bottom trawling, because of the fact that bottom trawling fisheries might not target the same target species as marine mammals or they get entangled less in trawling nets. However, even though these effects might be smaller when compared to pelagic fisheries, there is still a considerable impact, and noise pollution from trawlers might be even worse than that of pelagic fisheries (Daly et al. 2021).

The impact of bottom trawling on marine mammals should not be underestimated, and more research on the interactions between them can help to properly examine these impacts. Based on the conclusions made here, but also the gaps identified in the research available, there are some suggestions or considerations for future research. One of the bigger impacts of bottom trawling is on the behaviour of marine mammals, both due to generation of noise but also proximity to trawling vessels. However, not much research can be found on this topic, so future research should try to put more focus in this field. Another suggestion for future research is the application of an interdisciplinary approach to the research of impacts of bottom trawling on marine mammals. This is because the impacts of bottom trawling happen on an interdisciplinary level, a combination of, among others, physiological, behavioural and population level.

Afterword

No content generated by AI technologies has been presented as my own work.

I wrote the Bachelor's thesis on the topic of bottom trawling because it is a topic that has piqued my interest for quite some time, and I have wanted to dive into some of the literature on it. I also plan on doing my masters in Marine Biology, which encouraged me to pick a topic in that field. Even though not much time was allocated towards writing this Bachelor's thesis, I still felt I was able to deepen my understanding of the topic, and with proper planning, I was perfectly able to finish the thesis on time.

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