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Vessel Strike Prevention Measures for Marine Animals and their Effectiveness

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Abstract

The threat of vessel strikes on larger marine species continues to grow each year with the species affected ranging from sea turtles to whales. Injuries to the impacted animals can be fatal, which is particularly alarming for conservation efforts as many of these species are at greater extinction risk and listed on the IUCN Red List. To combat the issue of vessels striking marine animals, several efforts have been introduced; however, their effectiveness varies or is unknown. Published literature on the mitigation efforts targeting vessel strikes can be difficult to find as it is scattered and focuses primarily on large marine species. Some of the reports explain these efforts in detail and others investigate their impact on certain species. Here I review the existing literature on proposed mitigation efforts and their effectiveness to reduce vessel strikes on marine fauna. More research is needed to determine the true effectiveness of some of these efforts and more measures should be implemented to address the growing issue of vessel strikes.

Introduction

Maritime traffic has grown dramatically with time, with a study by J. Tournadre noting a four-fold increase from 1992 to 2014 [36]. Vessel traffic will only continue to grow with some models estimating an increase of 240 to 1,209% by 2050 [29]. This trend may appear alarming not only due to the environmental impacts of marine vessels, such as greenhouse gas emissions or garbage pollution, but also due to the possible increased incidence of vessels striking marine organisms [42]. These collisions can cause blunt force injuries or deep lacerations in marine animals that may result in death in addition to severely damaging vessels and injuring humans onboard [30, 37].

Vessel strikes are a threat to several species of marine vertebrates. A study by Ataman et al. on nesting loggerhead sea turtles (*Caretta caretta*) in Florida found that out of 60 specifically identified injuries, 75% were the result of a boat strike [1]. Florida manatees (*Trichechus manatus latirostris*) are also threatened by vessel strikes with impacts by watercraft accounting for 25% of deaths recorded from 1979 to 2004 and many bear the scars of at least one strike [22, 28]. Impacts by watercraft are the top source of anthropogenic injury and death for Florida manatees [17]. One of the largest threats facing whale populations in the modern day aside from net entanglement is vessel strikes [25]. Whale species like the blue (*Balaenoptera musculus*), humpback (*Megaptera novaeangliae*), and fin (*B. physalus*) whale see vessel strikes as a major cause of death off the United States West Coast [26]. Vessel strikes can often go unnoticed if the vessel is of significant size and may also be underreported for several reasons such as fear of reprisal [25]. These strikes pose a threat to the populations of several marine vertebrates, many of which are in danger of extinction and the true impact on some species may not be known due to their rapid healing [19, 44].

Marine animal behavior can put them in the path of oncoming vessels. Florida manatees are difficult to spot when surfacing and inhabit areas with poor water clarity. Sea turtles spend much of their time in nearshore shallow water to breathe, reproduce, and feed. Whales must surface to breathe, and, in the case of the rare Gulf of Mexico Bryde's whale (*Balaenoptera edeni*), it spends much of its time at night near the surface [10, 22, 35]. Due to marine animals' normal behavior putting them at risk of collision and their increasing risk of conflict with growing vessel traffic, methods intended to prevent the occurrence of strikes or reduce the severity of injuries to an organism are required. This paper will review several mitigation measures that have been implemented to prevent or reduce the severity of vessel strikes on marine organisms and their effectiveness.

Prevention Measures

Propeller Guards

One measure to reduce the severity of a vessel strike on marine fauna is the employment of a propeller guard. Propeller guards are often advocated to protect cetaceans like whales but this measure is not perfect [2, 38]. While the effectiveness of propeller guards on watercraft striking whales has never been tested, Work et al. used artificial carapaces to test the effectiveness of two commercial propeller guards in reducing the severity of small vessel strike injuries on loggerhead sea turtles [30, 48]. The two guards proved somewhat effective at idle speed but were completely ineffective at planing speed [48]. At planing speed, using the two guards resulted in catastrophic damage to the animal model just as it did when using an outboard motor with no guard over the propeller [48]. While the guards offer some protection from the propeller, the area of the motor foot increases with their use [48]. The carapace was not damaged when using an inboard or outboard jet motor at both idle and planing speeds, however [48]. The effectiveness of propeller guards appears to be slim, so they are best used in addition to other mitigation measures [23].

Speed Reduction

Reducing vessel speed is a simple mitigation strategy that can better protect smaller species like turtles and manatees. Sea turtles react to approaching smaller vessels by immediately moving away from the vessel's track or initially moving across or in line with the vessel's track before moving away [14]. Sea turtles also flee vessels less frequently as vessel speed increases with the most reliable response occurring with boats traveling at 4 km/h, much slower than what is typical on open water [14]. The severity of injuries on marine species decreases at lower speeds with the occurrence of catastrophic wounds on model loggerhead turtles falling from

100% at planing speed to 40% at idle speed in an experiment by Work et al. [48]. Florida manatees react to approaching boats by increasing their swimming speed and moving toward deeper water. Nowacek et al. found that a vessel's speed was not a significant factor in causing this response [22]. The researchers also concluded that slower vessel speeds could allow manatees sufficient time to move away from approaching boats as the manatees often reacted when a vessel was within 25–50m [22]. Slower vessel speed not only gives manatees a longer time to react but also increases the reaction time of vessel operators to signs of manatees allowing them to stop or alter course [3]. Slower vessel speeds can reduce the severity of blunt force injuries since the impact force is affected by a vessel's speed [3].

Speed reduction of vessels can also benefit larger creatures such as whales by decreasing the number of deaths. In 2016–2017 following the implementation of voluntary Vessel Speed Reductions in shipping routes off San Francisco, California, the number of deaths of humpback whales decreased by 9–10% while blue whale deaths decreased by 11–13% [27]. Rockwood et al. [27] found that if 95% of mariners followed a 10-knot speed limit within the shipping lanes, three times as many humpback whale deaths and twice as many blue whale deaths could be avoided. The North Atlantic right whale (*Eubalaena glacialis*) is extremely vulnerable to vessel strikes due to its small population, but Conn and Silber estimated that a 10-knot speed limit reduced the mortality risk of vessel strikes by 80–90% [5].

Speed restrictions effectively reduce vessel strike mortalities, but their status as voluntary or mandatory impacts their success. Boaters in Florida responded favorably to questionaries regarding the use of go-slow zones to protect sea turtles [10]. Off the coast of southern California, average vessel speed did not decrease, nor did vessels travel at or below the requested 10 knots [20]. The daily average speeds were also not reduced during the voluntary conservation program [20]. This is not always the case as mariners traveling around the Roseway Basin Area

on the Scotian Shelf reached a voluntary compliance rate of 71% within the first five months of implementation [41]. Vanderlaan and Taggart estimated this level of compliance to reduce the risk of lethal vessel strikes to North Atlantic right whales by 82% [41]. Speed restrictions are a simple and effective way to address the issue of vessel strike mortality, though low compliance with these programs can reduce their effectiveness.

Vessel Traffic Rerouting

Marine animals can be protected by separating vessel traffic from the location of different species. In 2014, the International Maritime Organization (IMO) adopted a Traffic Separation Scheme (TSS) to reduce encounters between ships and whales near Panama [12]. Implementing the TSS with a 10-knot speed limit was expected to reduce the number of vessel strikes by 93% [13]. Almost 90% of vessels complied with the TSS but very few complied with the recommended 10-knot speed limit [12]. The high compliance of mariners to the areas to be avoided (ATBA) and the speed reductions around the Roseway Basin Area were estimated to reduce the risk of lethal strikes to North Atlantic right whales by 82% [41]. Similarly, the use of a TSS in the Bay of Fundy could reduce the risk of lethal collisions with right whales by 62% according to Vanderlaan et al. [40], a 10% higher reduction than simply employing a 10-knot speed restriction. From a conservation perspective, rerouting vessels could be preferable to simply recommending speed restrictions because the rerouting of vessels lowers the possibility of a ship striking a whale rather than simply reducing the risk of a lethal strike [39].

Onboard Observers

Dedicated onboard observers placed on vessels can alert crews when organisms like whales are present [8]. The United States Coast Guard even requires a trained marine mammal lookout on any of its vessels traveling within 20 nautical miles of shore or through critical

habitats [8]. As recommended by the Whale and Dolphin Conservation Society, the observers should not be the sole preventive measure for ship strikes as their ability to detect whales can be hindered by vessel speed or environmental conditions [8]. A high-speed vessel traveling 38 knots would reach a whale at 200 m in just 10 seconds [43]. The practice is not always effective as Wiley et al. noted two incidences of noncommercial vessels with little reaction time striking North Atlantic right whales with marine mammal observers onboard [47]. The practice can, however, provide some protection to marine species. An observer placed onboard ferries near Massachusetts spotted whales first in 56.4% of cases, much higher than other crew members, and more often spotted whales at distances of over 400 m [43]. A study by Flynn and Calambokidis of observers placed onboard cargo vessels found that despite some initial skepticism by ship personnel, crews cooperated and assisted in sighting whales voluntarily [9].

Acoustic Deterrents

One strategy to prevent a collision between a ship and a marine organism that has been given little attention is acoustic deterrents. It is theorized that whales may not react to approaching vessels due to various reasons such as high levels of ambient noise in an area or the 'Lloyd Mirror effect,' where low-frequency sound is reduced or canceled at the surface, especially when the source is close [8]. Acoustic deterrents have been proposed as a mitigation measure to vessel strikes, but their effectiveness varies. In one experiment, 95% of manatees were found to exhibit an avoidance response when exposed to an underwater parametric alarm and reacted at a distance over three times greater than observed during alarm-off trials [11]. Loggerhead sea turtles were found to have a mild, aversive response to a simulated acoustic deterrent device [24]. Little consideration has been given to acoustic alerting signals due to knowledge gaps in their effectiveness and the potential for habituation and causing disturbance

[6]. The reactions of marine animals to acoustic deterrents could sometimes increase the risk of collision. North Atlantic right whales showed no reaction to approaching vessels in a study by Nowacek et al. [21], but when researchers exposed the whales to an acoustic alert, the whales reacted strongly by surfacing.

Mobile Phone Applications

Mobile phone applications are a recent technology that could reduce vessel strikes on marine animals. The application "Whale Alert" displays a ship's current location, seasonal management areas of whales, mandatory ship reporting areas, and areas to be avoided [46]. It also allows users to input sightings of whales or even report injured whales to authorities [45]. "Whale Alert" is used in the California Current sanctuaries, the Boston Channel, and southeast Alaska [4]. The effectiveness of applications like "Whale Alert" in reducing vessel strikes is unknown, but there is potential for their use [30].

Mandatory Ship Reporting (MSR) Systems

The Mandatory Ship Reporting (MSR) system aims to increase mariners' awareness of the risk of vessel strikes on whales [34]. The system requires mariners onboard vessels 300 tons or greater to report their vessel name, call sign, speed, course, location, route, and destination to a shore-based station [34]. After doing this, mariners receive an automated message consisting of the locations of the most recent (less than 24 hours) right whale sightings and information on sources describing avoidance procedures [34]. The message can also describe any additional regulations aimed at preventing strikes on whales such as speed restrictions [33]. The system ensures that mariners receive the most current information in real-time. Two MSR locations were created when the system was implemented in 1999 and they are placed in locations where and when right whale sightings are known to occur [33]. The first, off the coast of Massachusetts,

operates year-round, while the second, off the coast of Georgia and Florida, only operates from November 15 through April 15 [33]. The message from the MSR is advisory, and mariners are only required to report to the system, meaning that mariners can choose not to alter their actions based on the presence of right whales [34]. Silber et al. [33] found that between 1999 and 2013, mariners onboard most ships of 300 tons or greater did report to the MSR and traveled 10–16 knots, though the average speed decreased following speed restrictions around 2009. Despite the MSR system being in place, right whales off of Georgia and Florida continued to be killed, leading to the proposal for vessel speed restrictions and alternative routes in 2004 [16]. A 10-knot speed restriction would eventually become mandatory with a higher compliance rate compared to the voluntary speed reduction and the recommended alternative routes would also see high compliance [16]. The MSR system is not in itself an effective mitigation measure, but it is an effective education and outreach tool as hundreds of messages concerning the vulnerability of marine animals to vessel strikes are sent directly to ships each year [15, 33].

Real-Time Plotting of Cetaceans System (REPCET)

The Real-Time Plotting of Cetaceans System (REPCET) is a computer system database with a centralized server on shore and clients in the form of subscribed commercial ships [18]. By sharing reports of sightings, the system aims to reduce vessel strikes to observed whale species [7]. Observations of whales are transmitted to land-based servers via satellite where the data is centralized and sent to other REPCET-equipped ships [7]. The observations are mapped on a dedicated screen onboard vessels where observations can be quickly entered into the system [7]. The screen displays the position of the observation in addition to an area surrounding this point where the risk of encountering the individual animal is high [7]. The position of the observation remains marked for 24 hours to serve as a warning to mariners to remain vigilant [7].

The system offers many advantages as only authorized ships can view the location of the whales, preventing exploitation from whale-watching or whaling vessels [7]. The system also allows for the reporting of smaller cetaceans and floating objects that could be potential collision hazards [7]. Another advantage of the REPCET system is that it encourages collaboration between shipping companies and the research and conservation efforts taking place in the Marine Protected Areas where the system is implemented [18]. The REPCET is a cost-effective solution for addressing the issue of vessel strikes [32]. In a study focused on ship strikes of the Mediterranean fin whale subpopulation, the efficiency of the REPCET system was estimated to rise to 19% if all vessels operating in the Pelagos Sanctuary used the technology [31]. This shows that the technology should be used in parallel with other mitigation measures to be truly effective [31].

Early Warning System (EWS)

Off the coast of Georgia and Florida, right whales arrive in December to give birth [49]. Their presence in this location makes them vulnerable to strikes from ships. In 1994, the Early Warning System (EWS) was developed, and it operated by using aerial surveys that would report the locations of right whales in the calving grounds to all mariners in the area [49]. The aerial surveys offered additional benefits such as photographing right whales for later identification and using the data obtained on the flights to better understand right whale habitat, distribution, and reproduction [49]. Following its implementation, the EWS did not stop vessels from colliding with and mortality wounding right whales [16]. Aerial surveys also attempted to gather data from ships' Automatic Identification System (AIS) to assess the risk to right whales from vessels, but there are issues with using AIS for this purpose [16]. AIS is not required on military or smaller vessels and the data can only be collected by aerial surveys in clear weather [16]. This is no

evidence that aerial surveys like the EWS are effective in preventing vessel strikes and this method is highly dependent on weather conditions and the radio equipment a vessel carries as smaller vessels are likely less equipped [30].

Conclusion

The number of vessels traversing the ocean continues to increase, posing a threat to a variety of marine species ranging from turtles to whales. Many of the impacted species are vulnerable and the animals themselves may behave in ways that increase the likelihood of a strike [10, 22, 44]. These collisions can prove fatal, especially at higher speeds [48]. Vessels can also be damaged and crews can be injured in these strikes [37]. Several measures have been used to prevent or lower the severity of vessel strikes, though their effectiveness varies or is unknown. The most effective measures to prevent vessel strikes are reducing speed and rerouting vessels with animals suffering less catastrophic injuries when struck, reacting in time to properly avoid ships, and not encountering ships traveling through alternative routes [3, 5, 22, 39, 48]. The effectiveness of combining these measures can be seen in the observed or estimated risk of vessel strikes in the TSS and ATBA near Panama, the Roseway Basin Area, and the Bay of Fundy, but it is important to recognize that rerouting must be done carefully to not impact other species [13, 39-41]. Some other measures may prove somewhat effective such as propeller guards, onboard observers, the MSR system, and the REPCET system [15, 31, 43, 48]. Propeller guards, though, are only effective at idle speeds, observations by onboard observers can be affected by vessel speed or poor weather conditions, the MSR system is more effective as an educational outreach tool, and the REPCET system is most effective when paired with other prevention measures [8, 15, 31, 48]. Prevention measures like acoustic deterrents, mobile phone applications, and the EWS are either ineffective or their effectiveness is unknown. Acoustic deterrents can potentially be effective on species like manatees, but the reactions of other species like right whales may put them at risk or the animal could experience negative effects like habituation or disturbance [6, 11, 21] On the other hand, the effectiveness of mobile phone applications, despite their potential,

have not been studied and no evidence exists for the effectiveness of the EWS, which heavily relies on a ship's radio equipment and weather conditions [30].

It is important to understand the effectiveness of these prevention measures as the risk continues to increase. More research is needed as much of the available literature focuses on speed reduction and vessel rerouting with little focus on additional measures that could prove promising such as mobile phone applications. There are also knowledge gaps in the literature for prevention measures that could protect smaller species as few studies focus on protecting sea turtles or manatees through means other than reducing speed or taking alternate routes [11, 48]. Vessel traffic is only expected to increase, and many vulnerable species will require action to be taken to protect them from this growing threat and these measures must be effective in reducing strikes.

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