Cetacean conservation in the Yarari Sanctuary: which measures need to be taken?

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An evaluation of conservation measures needed for cetaceans in the Yarari Marine Mammal Sanctuary in the Dutch Caribbean

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Abstract

Cetaceans play an important role in the functioning of natural ecosystems. The Caribbean Sea serves as an important foraging, breeding, and birthing area for an array of cetaceans, which led to the establishment of the Yarari Marine Mammal Sanctuary in 2015. Currently, no additional conservation measures are in place to protect important cetacean species that reside in and pass through this mammal sanctuary, i.e. the humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), short-finned pilot whale (*Globicephala macrorhynchus*) and the common bottlenose dolphin (*Tursiops truncates*). An extensive literature review and interviews were performed to examine which threats these cetaceans encounter in the Wider Caribbean Region (WCR). This information was subsequently used to determine which conservation measures should be implemented in the Yarari Sanctuary. The main result was that there was little to no data available for the Yarari Sanctuary. Therefore, recommendations for specific problems in Yarari could not be made. It was found that vessel strikes, marine pollution, climate change, and habitat degradation are a threat in the WCR, and possibly the Yarari Sanctuary.

Based on information obtained for the WCR, the following measures could benefit the conservation of cetaceans in the Yarari Sanctuary: 1) redirection of shipping lanes to reduce vessel activity in and around the sanctuary, 2) implementation of vessel speed restrictions, 3) implementation of a ban or tax on single-use plastic, 4) marking fishing gear with ownership labels or with GPS trackers to reduce wilful discarding of fishing gear, 5) revision of contingency plans to manage and contain oil and chemical spills, 6) seasonal closures for industrial works to reduce the impact of underwater noise, and 7) maintaining and connecting the Yarari Sanctuary's areas to mitigate the effects of climate change and habitat degradation. The main finding and limiting factor for this research is the reoccurring issue of gaps in available data, specifically for the Yarari Sanctuary. This indicates the severity and need for additional data and management strategies and raises questions as to how the purpose of the sanctuary is being upheld and maintained. As the available information is scant, it is currently not possible to establish a well-defined management strategy for the Yarari Sanctuary. It is therefore recommended that research is continued, and that long-term data are collected (5-10 years) to ensure that a specific management plan can be established. Collaboration and investing in tracking and monitoring programmes could further improve research outcomes.

Samenvatting

Walvisachtigen spelen een belangrijke rol in het functioneren van natuurlijke ecosystemen. De Caribische Zee dient als belangrijk foerageer-, voortplantings- en kalvergebied, waardoor in 2015 een beschermd gebied is opgezet; het Yarari Marine Mammal Sanctuary. Momenteel zijn er geen beschermingsmaatregelen geïmplementeerd om belangrijke walvisachtigen, zoals de bultrug *(Megaptera novaeangliae*), potvis (*Physeter macrocephalus*), Indische griend (*Globicephala macrorhynchus*) en tuimelaar (*Tursiops truncatus*) te beschermen binnen dit gebied. Een uitgebreid literatuuronderzoek en interviews zijn uitgevoerd om na te gaan met welke bedreigingen deze walvisachtigen in de gehele Cariben geconfronteerd worden. Deze informatie is gebruikt om te bepalen welke beschermingsmaatregelen toegepast moeten worden in het Yarari reservaat. Het belangrijkste resultaat was dat er weinig tot geen data beschikbaar is voor het Yarari reservaat, hierdoor konden geen specifieke aanbevelingen worden gemaakt. Uit het onderzoek blijkt dat aanvaringen met schepen, mariene verontreiniging, klimaatverandering en habitatfragmentatie de meest voorkomende bedreigingen binnen het Yarari reservaat kunnen zijn.

Op basis van de informatie die verzameld is voor de gehele Cariben, kunnen de volgende beschermingsmaatregelen bijdragen aan het beschermen van walvisachtigen in het Yarari reservaat: 1) het verleggen van scheepsvaartroutes om activiteit te verminderen binnen en rondom Yarari, 2) opleggen van snelheidsbeperkingen voor schepen, 3) verbod opleggen of het heffen van belastingen op eenmalig gebruik van plastics, 4) het merken van vistuig met eigendom of GPS zenders om het afleggen van vistuig te verminderen, 5) invoering van noodplannen om olie- en chemische verontreiniging te beheersen, 6) seizoensafsluitingen inlassen voor industriële werkzaamheden om overlast van onderwatergeluid te verminderen, en 7) het in staat houden en verbinden van het Yarari reservaat gebieden om zo de gevolgen van klimaatverandering en habitatfragmentatie te verminderen. De belangrijkste beperkende factor in dit onderzoek is het steeds terugkerende probleem van het gebrek aan data voor het Yarari reservaat. Dit onderzoek geeft niet alleen aan hoe ernstig dit gebrek is, maar ook de noodzaak voor meer informatie en beschermingsmaatregelen. De vraag is hoe de doelstelling van dit gebied momenteel bekrachtigd en onderhouden wordt. Door een gebrekkige hoeveelheid informatie is het nu niet mogelijk om een goed gedefinieerd beheersplan op te stellen voor dit gebied. Het wordt daarom aanbevolen dat onderzoek doorgezet wordt en dat dit op lange termijn gebeurt (5-10 jaar) om ervoor te zorgen dat een specifiek beheersplan opgezet kan worden. Daarnaast zijn samenwerkingen en het investeren in monitoringsprogramma's van belang voor de doeleinden van dit onderzoek.

Contents

List of abbreviations

ATBA	Area To Be Avoided
DCNA	Dutch Caribbean Nature Alliance
FAD	Fish Aggregating Device
IMMA	Important Marine Mammal Area
IMO	International Maritime Organization
IUCN	International Union for Conservation of Nature and Natural Resources
IWC	International Whaling Commission
LNV	Dutch Ministry of Agriculture, Nature and Food Quality
MMC	Marine Mammal Commission
MPA	Marine Protected Areas
NGO	Non-governmental organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PSSA	Particularly Sensitive Sea Area
SEFSC	Southeast Fisheries Science Centre
SPAW	Protocol for Specially Protected Areas and Wildlife
WCR	Wider Caribbean Region
WUR	Wageningen University and Research
WWF	World Wide Fund for Nature

1 Introduction

There is growing evidence that top predators, such as cetaceans, commonly known as whales, dolphins, and porpoises, play an important role in the functioning of natural ecosystems (Roman et al., 2014). Scientists revealed that one of the biggest contributions cetaceans make to the ecosystem is circulating nutrients. They do this while diving for food, during migration, and by fertilizing ocean waters with their excretions (Roman et al., 2014; Doughty et al., 2016). Cetaceans defecate close to the surface and hereby release valuable substances such as nitrogen and phosphor into the water column, which serves as food for (phyto)plankton (Garcia Cegarra et al., 2021). Another way cetaceans facilitate nutrient transfer is by transporting nutrients from high latitude feeding grounds to low latitude breeding grounds all over the world (Roman et al., 2014; Moss, 2017).

Besides benefitting the nutrient flow throughout the ocean, cetaceans also play an important role in the carbon cycle. As with phosphor, cetaceans can distribute carbon throughout different ecosystems and ocean layers through their movement patterns. Cetaceans also enable carbon fixation by producing food for (phyto)plankton, producing plankton blooms, which are then able to sequester more carbon (Bristow et al., 2017; Martin et al., 2021). Cetaceans also play an important role in the sequestering of carbon through accumulation in biomass, which can be stored throughout their entire lifespan and even after death carbon can be fixated into new ecosystems through whale falls (Cook et al., 2020). Whale falls are not only beneficial for carbon fixation, but also provide a food source for a range of organisms living in the deep sea. Different stages of decomposition support different types of organisms and some specialist organisms only thrive because of these types of organic falls (Silvia et al., 2021). Not only do cetaceans play an important role in the food chain after their deaths, but other organisms, such as species of tuna and seabirds, also benefit from them being alive. These species often use the sounds cetaceans make as indicators of prey presence, forming a positive interaction between a multitude of species (Veit & Harrison, 2017).

It is clear that cetaceans play an important role in both the cycling of nutrients and sequestering carbon. However, due to threats worldwide, the cetacean population has decreased by 66 to 90 percent since pre-whaling times (Roman et al., 2017). This substantial decrease has had an effect on the role cetaceans play in the marine habitat. According to calculations made by Roman et al. in 2014, cetaceans used to transport around 340 million tonnes of phosphorus per year. However, today, this phosphorus transportation is only estimated at 75 million tonnes per year, more than three quarters less (Doughty et al., 2020). Furthermore, it has been estimated that the loss of cetaceans has resulted in a decrease in carbon sequestration by roughly 86% (Durfort et al., 2021; Pershing et al., 2010).

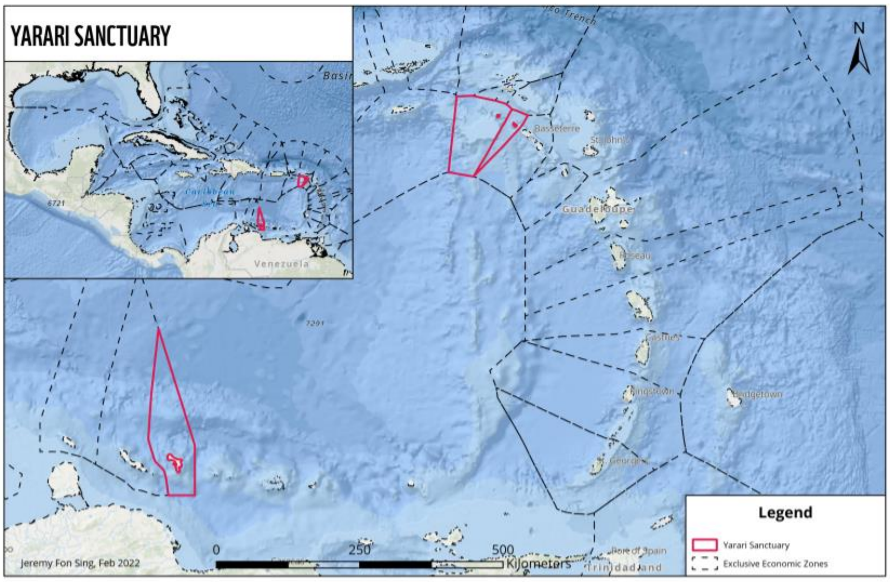
The largest part of the past decline in cetacean populations was caused by whaling activities. Although whaling was banned under the International Whaling Commissions' (IWC) moratorium in 1986, more than 56.800 whales have since been killed by whalers (IWC, 2018). Nowadays, the biggest threat to cetaceans is being caught as bycatch in fishing nets, which is the cause of approximately 300,000 deaths per year (Young & Ludicello, 2007; WWF-International, n.d.-a). Cetaceans are also falling prey to other anthropogenic threats, such as chemical pollution, noise pollution, and oil and gas development which are all contributing to habitat degradation (Sanganyado & Liu, 2020; WWF-International, n.d.-b). Other threats, such as ship strikes and marine litter, are also known to be the cause of many direct deaths of cetaceans (Sá et al., 2021).

Another major threat cetaceans face is climate change, resulting in an increase of the ocean temperature, rising sea levels, acidification, and changes in ecosystems. Moreover, rising temperatures may increase susceptibility to diseases and decrease reproductive success, which results in a further decline of cetaceans (EEA, 2016). In a study by Sousa et al. in 2019, it is concluded that climate change also contributes to a change in the geographical distribution, seasonal migration patterns, and behaviour of cetaceans. This change is resulting in shifting migratory patterns due to changes in prey abundance, which have also been affected by climate change or pollution and overfishing (Eklöf et al., 2020; Simmonds & Elliot, 2009; Sousa et al., 2019).

Cetaceans play an important role in the marine ecosystems but are no longer able to do this without facing an array of threats. Both types of threats have considerably reduced the cetacean population, which has negatively affected marine ecosystems, and has resulted and will keep resulting in loss of biodiversity (Doughty et al., 2016; Roman et al., 2014; Sousa et al., 2019). Fortunately, these issues are becoming more prominent, and action is being taken. However, due to lack of political priority, regulation, and enforcement these issues are still not being resolved as quickly as is necessary (Reeves et al., 2013; WWF-International, n.d.-a). This is why conservation measures need to be implemented to be able to protect cetaceans worldwide. In order for conservation measures to work, these will need to be taken in areas which are of high value to cetaceans, such as the Caribbean Sea.

The Caribbean Sea is an important area for cetaceans in the breeding season because of its warm tropical waters and some species even reside there all year round (New Bedford Whaling Museum, n.d.). A list of cetaceans that have been sighted in the Caribbean Sea can be found in Appendix A. As the Caribbean Sea serves as an important area for cetaceans, the Yarari Marine Mammal Sanctuary was established in 2015. The focus of this sanctuary is to protect the sharks and marine mammals that reside there both permanently and seasonally (BioNews18, 2015). The Yarari Sanctuary is split up into two areas (Figure 1), in which the south area is called the Leeward, consisting of the island Bonaire and the north area, called the Windward consisting of the island Saba and St. Eustace (Debrot et al., 2011; Debrot et al., 2017). This sanctuary was not only established for protection but also for research purposes, focussing on behavioural aspects and on impacts of certain threats (BioNews18, 2015).

Figure 1 Map of the south Leeward and north Windward locations of the Yarari Marine Mammal Sanctuary in the Caribbean Sea (Fon-Sing, 2022).



Esri, GEBCO, DeLorme, NaturalVue, GIS4C, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, FAO, NOAA, Esri, GEBCO, DeLorme

Frequent visitors to the Yarari Sanctuary are the humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), short-finned pilot whale (*Globicephala macrorhynchus*) and the common bottlenose dolphin (*Tursiops truncatus*). Individuals of these four species of cetacean have been found to both pass through the Caribbean Sea and the Yarari Sanctuary and have also been found to reside in the Yarari Sanctuary. As mentioned before, the Yarari Sanctuary was established to protect sharks and marine mammals from human induced treats. However, it is largely unknown which anthropogenic threats these four species of cetacean face while residing in and around the Yarari Sanctuary. Due to the variety in geographical and temporal distributions of the four chosen species of cetacean, understanding which threats they face will give a broad overview of what threats other species of cetacean might encounter while residing in and around the Yarari Sanctuary.

In addition to not knowing which specific threats cetaceans face, it is also unknown what conservation measures should be taken to be able to protect cetaceans in and around the Yarari Sanctuary in the future. Therefore, the main question that is answered in this report is – *What conservation measures can the Dutch Caribbean take to protect cetaceans, specifically the Humpback whale, Sperm whale, Short-finned pilot whale and Common bottlenose dolphin, residing in and around the Yarari Sanctuary, to reduce threats of anthropogenic origin?* – and the following sub questions are:

I. What are the geographical and temporal distributions of the Humpback whale, Sperm whale, Short-finned pilot whale and Common bottlenose dolphin within and around the Yarari Sanctuary?
II. Which anthropogenic threats do the Humpback whale, Sperm whale, Short-finned pilot whale and Common bottlenose dolphin face while residing in and around the Yarari Sanctuary?
III. What measures exist for cetacean conservation and which measures are currently taken to protect cetaceans by the Yarari Sanctuary?
IV. What are the most effective measures that can be taken to protect cetaceans in and around the Yarari Sanctuary?

This study focuses on conservation measures and policies the Dutch Caribbean can take and establish to protect cetaceans against anthropogenic threats they encounter while residing in and around the Yarari Sanctuary. To answer the main question of this report, a conclusion is made based on relevant literature, existing conservation measures, and interviews held with experts on cetaceans. In addition, an advice is formulated regarding the conservation measures the Caribbean Island governments can take in the Yarari Sanctuary in order to protect cetaceans. This study can also serve as a guide for other countries willing to protect cetaceans against various threats. The main goals are to 1) gain insight into the geographical and temporal distribution of species residing in and around Yarari Sanctuary, 2) to better understand the threats they face while residing in and around the Yarari Sanctuary, and 3) to formulate recommendations for cetacean conservation in and around the Yarari Sanctuary.

Although all species will be subject to anthropogenic threats during their stay in and around the Yarari Sanctuary, it is expected that species such as the common bottlenose dolphin, which reside near Yarari all year-round, are more affected by local human influences and will therefore face more threats such as released toxins and human harassment. Moreover, it is expected that all of the four chosen species face some of the same threats due to climate change but are also highly likely to be threatened by entanglement in fishing gear and marine debris. Thus, a lot of measures that can be implemented will be beneficial for many different species.

2 Methodology

To answer the main question of this report, a qualitative literature review was performed and analysed using two different techniques. In addition to the literature review, interviews with a varied group of experts were carried out to further substantiate the found literature.

2.1 Study Species

This report focuses on *M. novaeangliae*, *P. macrocephalus*, *G. macrorhynchus*, and *T. truncatus*, as these species of cetacean are known to migrate to and from or reside in the Yarari Sanctuary. The selection of these species was based on the number of sightings in the study area and their IUCN status. By focussing on species with a range of different geographical distributions and IUCN statuses, a broad spectrum of threats could be taken into consideration. Supplementary information on these species can be found in Appendix B.

2.2 Literature review

The literature review was carried out by using different search engines (Table 2.1.1). The most used search engines were Google Scholar and Science Direct, as scientific reports were required to analyse the current situation of the four species of cetacean and potential threats they might encounter in and around the Yarari Sanctuary. Another way scientific research was found, was by using the Wageningen University library. Besides scientific research, the search engine Google was used to bring variation and different perspectives into the review. Google was mainly used to assess a variety of websites about the specific species and the threats they face. To get a thorough understanding of the research topic a few main search topics were used. To filter the search results, these main topics were split up into keywords (Table 2.2.1). These keywords were used in both English and Dutch to improve and broaden the number of search results. In addition to the search topics, references out of gathered literary sources were also used to broaden the review.

Table 2.2.1 The search engines, main search topics and keywords consulted during the entire research.

Search Engines		Main Search Topics		Keywords Used	
				English	*Dutch*
Google	I	Threats to	I	IUCN status	IUCN status
Google Scholar		cetaceans		Deaths by threats	Dood door bedreigingen
ScienceDirect		Conservation		Sperm whale	Potvis
		measures		Humpback whale	Bultrug walvis
				Short-finned pilot whale	Indische griend
				Common Bottlenose dolphin	Tuimelaar
WUR library	II	Yarari		Threats to cetaceans	Bedreigingen walvisachtigen
		Sanctuary		Vessel strikes	Aanvaringen
				Underwater noise	Onderwatergeluid
				Marine litter cetaceans	Zeeplastics walvisachtigen
				Pollution cetaceans	Vervuiling walvisachtigen
				Climate change cetaceans	Klimaatverandering walvisachtigen
				Whaling activities	Walvisjacht
				Tourism cetaceans	Tourisme walvisachtigen
				Habitat conservation	Gebiedsbescherming
				Fishing activities cetaceans	Visserij walvisachtigen
				Conservation measures cetaceans	Bescherming walvisachtigen
				Map of Yarari	Kaart van Yarari
			II	Cetacean movement in Yarari	Walvis bewegingen in Yarari
Websites Used					
IUCN	WWF				
BioNews18	NOAA				

The available literature was reviewed by using two reviewing techniques, a scoping review and a critical review. During the scoping review, the existing literature was broadly consulted per research topic to identify important information, such as knowledge gaps, current issues, and regarding policymaking. This first part of the review also aimed to find suitable literature that met the pre-defined search criteria (Table 2.2.2). The literature found, was evaluated by data and relevance trough reading the title and abstract, and by using scientific literature published no longer than 10 years ago to ensure the literature was up to data and relevant for the period in which this report was written. The second part of the literature review, the critical review, was used as a more specific method to examine the literature in more detail and to contrast and evaluate a variety of viewpoints.

Table 2.2.2 The criteria that were used to select relevant literature for this report.

Usable literature	**Unusable literature**
Preferably reports written in, or after the year 2012 or before the year 2000 to ensure the literature is up to date and relevant	Websites, IUCN status and factual numbers from literature published before the year 2000
Peer reviewed reports or reports published in a journal	Websites stating facts and numbers that can be found in published peer reviewed reports
Reports on the Yarari Sanctuary – also if not peer reviewed	Reports about cetaceans in other parts of the world
Reports found in the references of other scientific reports or referred to by experts during the interviews	Reports and websites stating facts or information with no additional explanation or reference (no scientific substantiation)
Trustworthy websites (trustworthy: big organizations (WWF) and websites based on scientific information like NOAA and EOS Wetenschap)	Reports that contain writers' opinions based solely off of the writers own opinions and not substantiated by scientific literature
Reports and websites written in English or Dutch	Reports in foreign languages, excluding Dutch

2.3 Interviews

In addition to the literature review and to add to the quality of the research, semi-structured interviews were conducted to complement and validate the obtained and used information from the literature review. The interviews were mainly used to obtain data on policies regarding cetacean management, on datasets regarding the distribution of cetaceans and threats they might face and the protection measures that could be implemented (Appendix C). All interviews were conducted via MS Teams or Zoom and lasted for approximately 30-45 minutes. A total of nine interviews were conducted with experts from different establishments (Table 2.3.1). The selection of participants was based on two aspects, I) the company they worked for and their role in this company and 2) their knowledge and expertise on specific cetaceans. Prior to the start of the interview, all interviewees were asked to give consent to the recording of the interviews and permission to use the obtained information in this report. Subsequently, the obtained information from the interviews was analysed and filtered on relevance for this report.

Table 2.3.1 Participants for the interviews along with the interview topics.

	Interviewee	**Topic of Interview**
I	Yoeri de Vries (Ministry of LNV)	Current and future policy on cetaceans
II	Shane Gero (Sperm whale researcher)	Data on geographical distribution in the Caribbean, shipping routes, threats, species knowledge
III	Dolfi Debrot (WUR)	
IV	Tadzio Bervoets (DCNA)	
V	Jeffrey Bernus (CCS)	
VI	Chris Johnson (WWF)	
VII	Jerome Couvat (CARI'MAM project)	
VIII	Felicia Vachon (PhD on sperm whales)	Threats to sperm whales
IX	Hans Verdaat (WUR)	Access to data and where to find data

2.4 Data analysis

To analyse the literature found during the literature review, two analysing methods were used, a within-study literature analysis and a between-study literature analysis (Onwuegbuzie et al., 2012). The within-study analysis aimed to rigorously examine individual sources and obtain the most important and necessary information, while the between-study analysis aimed to not only look at sources individually but compare the information within to gain insight into potential contrasts. Both methods were used throughout this research, ensuring not only the contents of some specific literature was included but also that the findings were compared to each other and accessed. This comparing approach was also used to analyse the possible mitigation measures for each threat. Whereafter the best measure was chosen based on scientific research and data stating that the concerning measure is effective.

As the interviews were semi-structured, which meant that both the interviewer and the interviewee were able to steer the interviews in certain directions, two analysing techniques were used to decode the interviews. First the deductive analysis was applied, a more specific and organised approach of analysing the interviews. By first creating several topics of interest (based on the interview questions) and subsequentially linking obtained information and statements to these topics, a list was created which included relevant information per pre-chosen topic. In addition, a second analysing technique was used to highlight important topics and findings that were not pre-chosen and were added into the interview by either the interviewer or the interviewee. By using both of these techniques to analyse the findings from the interviews, all information relevant to this research was highlighted in a structured way and included information that did not fall under the pre-chosen topics (Appendix C) (Azungah, 2018).

2.5 Data validity

The validity of this research was ensured by the use of two sets of different analysing techniques in both the literature and interview analyses. Furthermore, all interviews were conducted with external experts and were all carried out by two individuals using the same structure. The interviews were all recorded, and transcriptions were made to ensure the reliability of the findings. Finally, all collected information and data were organised and placed into separate categories to ensure that no information went missing or was not included in the report.

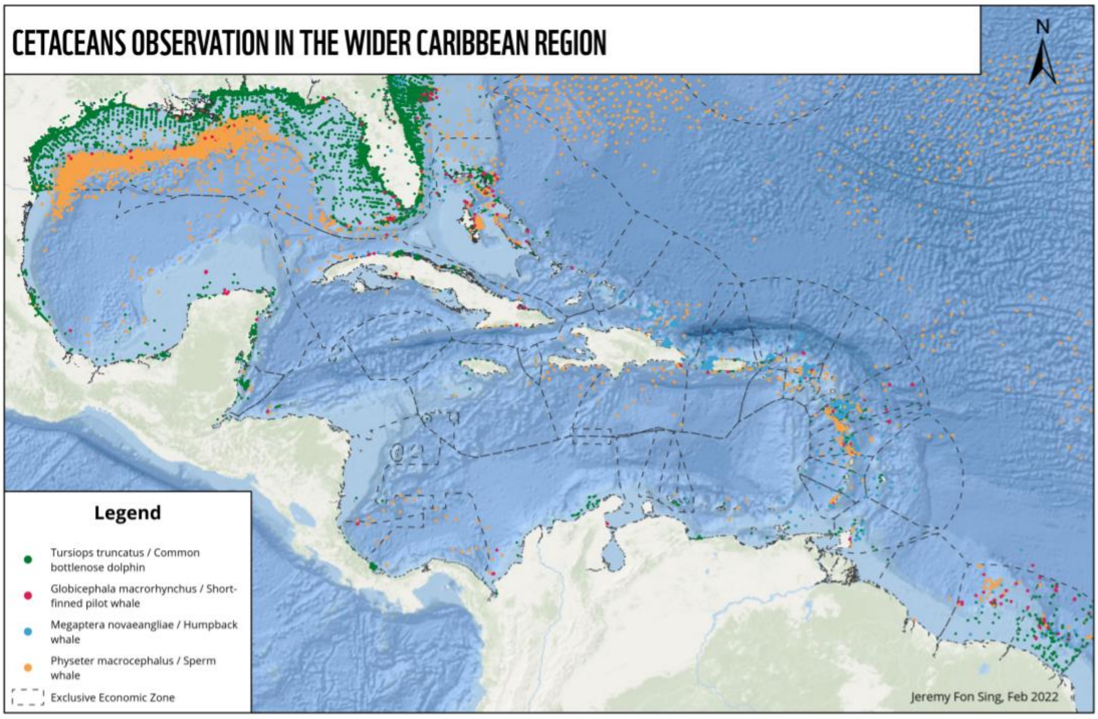
3 Results

An overview is given of what is currently known regarding the geographical and temporal distributions of the study species in the Wider Caribbean Region (WCR) and more specifically, the Yarari Sanctuary. This chapter will then proceed to define which threats cetaceans face and what measures can be taken to mitigate the subsequent effects. This section is mainly based on the obtained literature. The data that has been used to create the maps regarding species distribution, fishing and vessel pressure originate from the interviews.

3.1 Geographical and temporal distributions

The collected data on sightings within the WCR show that there is a lot more data on cetacean sightings near the coast in comparison to the open waters (Figure 3.1.1). Overall, most sightings are either of sperm whales or common bottlenose dolphins and are most frequently reported in the northern part of the WCR. Humpback whale sightings mainly occurred off the islands off the lesser Antilles (Leeward and Windward islands). The least sightings occurred for the short-finned Pilot whale. When they were sighted, this was mostly off the coast of the Bahamas in the Northern part of the WCR. The cetaceans that were sighted farthest away from the coast were the sperm whale and the common bottlenose dolphin, as seen in the centre of the Gulf of Mexico.

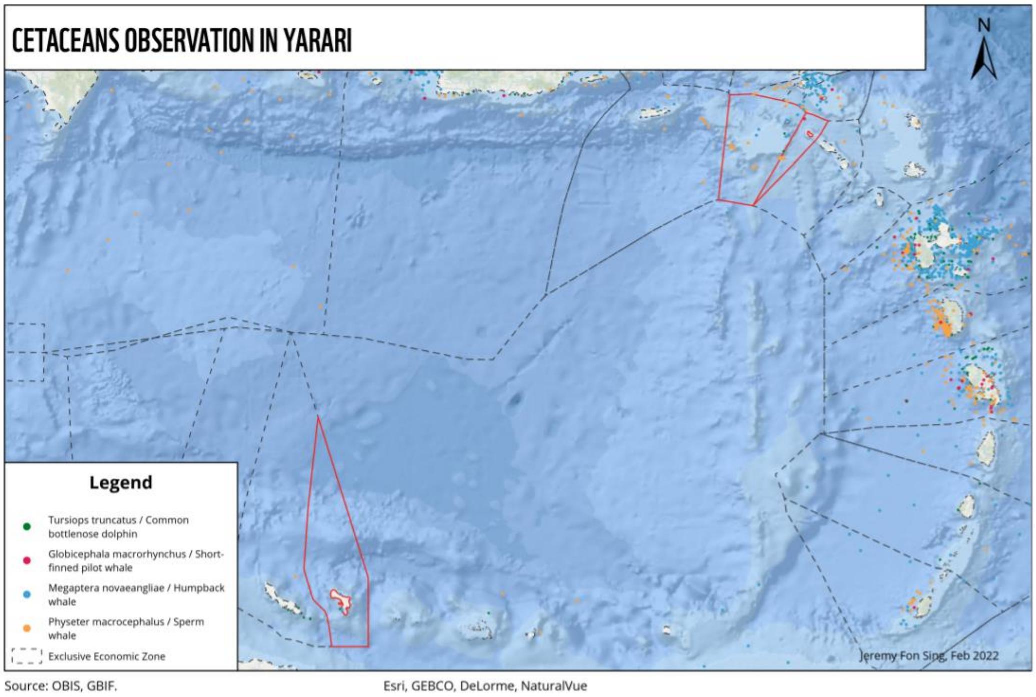
Figure 3.1.1 Map of sighting data of the short-finned pilot whale, humpback whale, common bottlenose dolphin and sperm whale from 1980-2020 in the Wider Caribbean Region (Fon-Sing, 2022).



Source: OBIS, GBIF. Esri, GEBCO, DeLorme, NaturalVue

Specifically focusing on the Yarari Sanctuary, it has been found that there is limited data regarding the sightings in this area. There have been more sightings near the island of Saba in the northern part of the sanctuary, than near the island Bonaire in the southern part of the sanctuary. Moreover, there has been a single reported sighting in Bonaire between 1980 and 2020 of a common bottlenose dolphin. Although sightings of sperm whales, humpback whales, and short-finned pilot whales have been recorded in the northern part of the sanctuary, this is to a far lesser extent than in the rest of the WCR (Figure 3.1.2).

Figure 3.1.2 Map of sighting data of the short-finned pilot whale, humpback whale, common bottlenose dolphin and sperm whale from 1980-2020 in the Yarari Sanctuary (Fon-Sing, 2022).



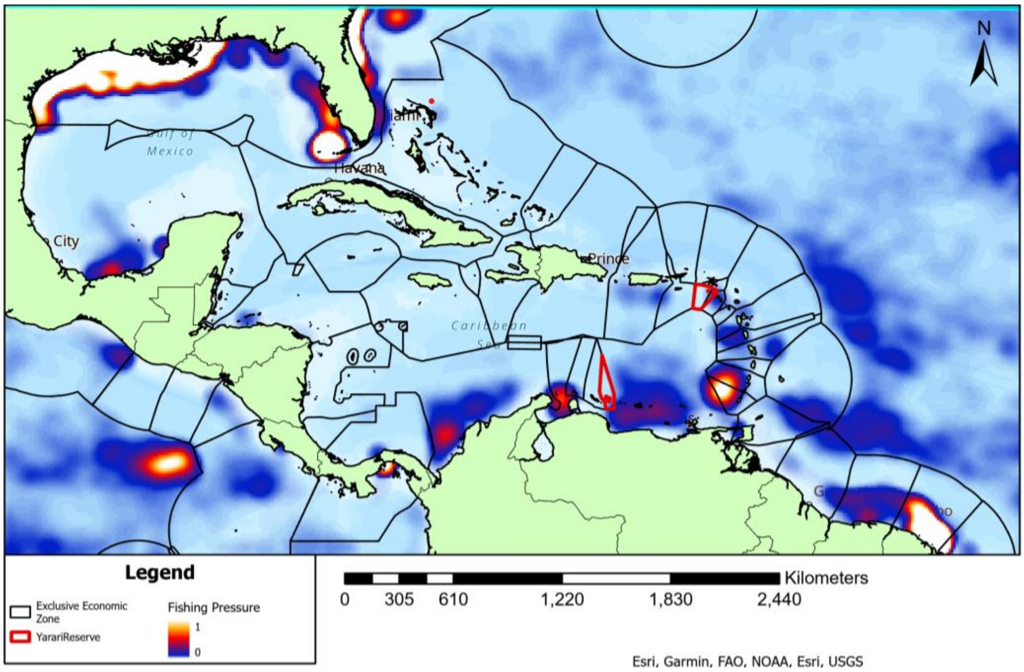
3.2 Threats in the Wider Caribbean Region

Cetaceans that reside in the WCR are subject to a range of threats. This chapter focuses on anthropogenic threats to cetaceans and the leading factors of habitat degradation. A description of each threat, its occurrence, and the mitigation measures that can be taken are described for the WCR, and specifically the Yarari Sanctuary.

3.2.1 Fishing activity

Fishing vessels can threaten cetaceans through being caught as bycatch or entanglement in fishing gear, and through habitat destruction and depletion of prey resources. The removal of prey through fisheries mainly affects toothed whales, as baleen whales usually do not feed in the WCR (Morissette, 2010). Bycatch of cetaceans is one of the most well-documented threats to cetaceans worldwide. However, during the literature review the extent to which bycatches occur in the WCR seemed less well documented than the occurrence of entanglements. Fishing pressure can be used as a proxy for the extent of cetacean bycatch and is most documented along the coasts of the WCR (Figure 3.2.1). There is very limited data available regarding fishing pressure in offshore areas. A large number of Caribbean countries rely on fishing activities for food and income (FAO, 2014). The majority of these fisheries have been associated with sustainability issues regarding their practices and fishing techniques (CLME, 2013). At least 18 species of marine mammal have been reported to have interacted with fishing gear in the WCR, and at least 16 species have been caught as bycatch (Bjorkland, 2011).

Figure 3.2.1. Map of Fishing Pressure in the Wider Caribbean Region with data from 2012-2020 (Fon-Sing, 2022).



According to Gero & Whitehead (2016) it is estimated that 20 sperm whales were entangled in the WCR in 2015. Two more incidents, that took place in 2013 and 2016, resulted in juvenile sperm whales becoming entangled in fishing gear, using Fish Aggregating Devices (FADs) in Guadeloupe (Rinaldi & Rinaldi, 2014). Research has shown that FADs and the debris from FADs are the greatest threat to sperm whales, and as the use of FADs is increasing, there is a significant concern regarding an increase in entanglements (IWC, 2019; J. Couvat, personal communication, 15 December, 2021). There is limited information on entanglements of smaller cetaceans in the WCR. However, a study using photo-identification did discover injuries on bottlenose dolphins that were most likely human-related and caused by interaction with fishing gear (Luksenburg, 2014). Although data regarding fishing pressure is available, the extent of the threat is still unclear in the WCR and in the Yarari Sanctuary.

3.2.1.1 Fishing activity: mitigation measures

As the amount of cetaceans that are being taken as bycatch varies per type of fishing gear, a range of mitigating measures can be taken to reduce the amount of entrapment and entanglement. The first measure that can be taken is to alter the fishing gear to either allow caught cetaceans to escape or to reduce the chance of entrapment. Some species of cetacean, mainly bottlenose dolphins, are known to chew through nets and to eat what is trapped in the net. However, while doing so, the risk of becoming entangled substantially increases. By reinforcing net structures and using different materials, the possibility for cetaceans to become entangled in the nets becomes increasingly smaller as they can no longer chew trough to make holes (Sacchi, 2021). In addition, in 2014 Kraus et al. found that painting fishing ropes either a different colour or luminescent, increases visibility and makes them more detectable for cetaceans.

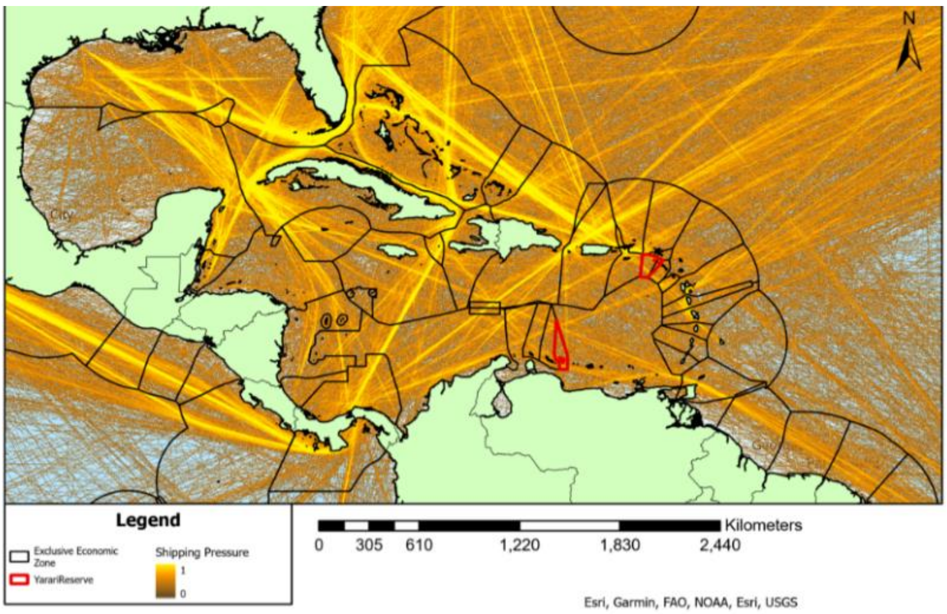
Another measure is to change fixed links into weak links, denoting that links between buoys, ropes, and nets become weaker, breaking under pressure that is maintained for a long period of time. This modification would make it easier for large cetaceans to free themselves from entanglement and is commonly known as a break-away line (Werner et al., 2006). Similar to weak links, fishing hooks can also be made to be more pliable by deforming and bending under pressure, making it easier for cetaceans to escape (McLellen et al., 2015). Mitigation measures, such as acoustic deterrents are also used in fisheries. However, it has not proven effective for all species of cetacean and can even lead to auditory damage if used wrong (Schoeman et al., 2020). However, there are other measures that enhance the acoustic reflection of the fishing net that have proven to reduce the amount of bycatch. Nets can either be made thicker or be coated in a metallic-based substance. A study by Gazo et al in 2008 found that increasing a nets acoustic reflectivity reduced cetacean interaction by 50% and another study by Brotons et al in 2008 found that implementing this measure reduced interactions between cetacean and net by 49%.

Bycatch of cetaceans can also be reduced by adapting fisheries management legislation. This could include implementation of catch limits, fish effort limitations, gear restrictions, and seasonal closures. Most of these measures are drawn up to protect commercially fished species from being overexploited and not specifically to protect cetaceans from being taken as bycatch. However, there are rules and guidelines specifying how cetaceans should be handled after they have been caught. These guidelines ensure a maximum chance of survival after the animal has been caught and released back into the water (Schoeman et al., 2020). In rare circumstances, specific gear types can even be banned from use in a specific area, mostly consisting of gillnets or trammel nets (Gilman, 2015)

3.2.2 Vessel strikes

Vessel strikes are a danger to marine animals worldwide. Collision between a marine mammal and a vessel can result in serious injury and death (Vanderhoop et al., 2013). In the Caribbean Sea, this is one of the main threats to cetaceans as the shipping activity is high in this region, especially cargo ships and ferries (Figure 3.2.2). Records of collisions within the Caribbean Sea date back to 1961. These reports include collisions with sperm whales, and a near-collision between a humpback whale and a high-speed fishing vessel. Propellor scars on smaller cetaceans leads researchers to believe that these smaller species are also threatened by vessel strikes (IWC, 2014). Whale watching activities are also known to lead to an increased amount of collisions with cetaceans (Heenehan, 2019).

Figure 3.2.2 Shipping pressure in the Wider Caribbean Region from the year 2016 (Fon-Sing, 2022).



3.2.2.1 Vessel strikes: mitigation measures

There are a number of mitigation measures that have been developed to reduce the amount of vessel strikes with cetaceans. The first measure includes redirecting shipping lanes to avoid interaction with cetaceans either migrating through an area or which are known to permanently reside in the area. The changes made to shipping lanes can be seasonal or permanent, obligatory or optional, and can be subject to all vessels or only certain types of vessels (Schoeman et al., 2020). The governing body is responsible for drafting plans to redirect shipping lanes, but these plans have to be endorsed by the International Maritime Organisation (IMO) (IMO, 2014). However, alterations that are planned on being made to shipping lanes in territorial waters are permitted to be carried out without further approval from the IMO. Redirection of shipping lanes is perceived as one of the most effective mitigation measures and has proven to reduce vessel strikes by 60-95%, depending on the geographical region and specific requirements of the plans (Schoeman et al., 2020).

The second measure includes the implementation of speed restrictions when approaching or passing cetaceans to avoid distress and injury. A study by Vanderlaan & Taggart in 2007, found that by reducing vessel speeds to less than 10 knots (18.5 km/h), the chance cetaceans would sustain lethal injuries decreased to less than 50%. Plans to implement maximum vessels speeds outside of territorial waters also have to be endorsed by the IMO and can be seasonal or permanent, and subject to all or specific vessel types (Silber et al., 2012). A third measure that can be implemented, is by attaching an acoustic deterrent device onto the vessel which sends out signals to alert cetaceans that the vessel is coming. Although this type of mitigation measure was tested on specific cetaceans and proved to defer cetaceans from their swim ways toward the vessels, it has not yet been concluded that such devices work for all species of cetacean (Lagerquist et al., 2012; Nowacek et al., 2004). In addition, cetaceans may become habituated to the signal, no longer perceiving it as a warning (Schoeman et al., 2020).

The fourth measure that can be taken to reduce the amount of vessel strikes, is to place trained human observers on board. Trained observers were found to detect more whales and at a greater distance than the other crew members, giving the vessel enough time to manoeuvre out of the animals path (Flynn & Calambokidis, 2019). However, although these observers were effective in detecting cetaceans from large distances, larger vessels were found to not be able to react as quickly as needed. In addition, there have not been any studies that have concluded that onboard observers reduce vessel strikes substantial enough to make a difference (Wiley et al., 2016). The fifth measure includes the use technology to alert vessels of any cetaceans present in the area and to record sightings of cetaceans all over the world. For instance, there are certain mobile phone applications that can be used by both commercial and recreational vessels to upload GPS coordinates of cetacean observations to alert other vessels of their presence (Schoeman et al., 2020). GPS coordinates obtained from satellite images are also being used to alert vessels to the presence of cetaceans (NOAA, 2004).

3.2.3 Tourism

In the 1980s, both the Bahamas and the Dominican Republic began giving whale watching and swimming tours to the public. Commercial whale watching began in Dominica in 1988 and since then has been a growing industry attracting many tourists (Hoyt, 2007). Despite the fact that specific information for the WCR is lacking, it is known that in 2008 at least 21 nations and territories offered whale watching activities (Wiley, 2008). All forms of whale watching activities have a negative influence on the health of cetaceans by reducing their fitness and their population dynamics during foraging, resting, and socialising activities (Parsons, 2012; New et al., 2020). Other threats that whale watching create are noise and chemical pollution, physical and mental disturbance, and waste pollution; i.e. food packaging, drink cans and plastic bottles (New et al., 2020). Furthermore, whales and dolphins have been seen to abandon or leave their feeding and resting grounds due to continuous disturbances from whale watching activities (Parsons, 2012).

The Dominican Republic and Dominica are known to organise whale watching expeditions where clients can interact with humpback whales and sperm whales by swimming beside them (Sprogis et al., 2020; Gero & Whitehead, 2016). Not only does this cause disturbance but can also lead to habituation to humans. In Florida, vessel strikes have become more common because the dolphins have grown used to receiving human handouts, which influences their foraging behaviour and thus encourages the dolphins to swim towards vessels (Vail, 2016).

3.2.3.1 Tourism: mitigation measures

There are a range of measures that can be put into place to mitigate the negative effects of tourism. The first measure a governing body or the tourism industry can take is to formulate a code of conduct for observing cetaceans (Parsons & Woods-Ballard, 2003). These codes of conduct contain a set of rules that should be adhered to when going out to sea specifically to observe cetaceans in their natural habitat. As a code of conduct can be created by any governing body, industry, or individual business, there will always be differences in what is deemed as acceptable behaviour. Although the existence of these codes of conduct do assist in enforcing good practice, it has been concluded that the enforcement of these types of guidelines is too inadequate for them to make a substantial difference and mitigate all negative effects of the industry (Wiley et al., 2008).

A follow up measure that can be taken is to award tourism operators with a recognised label if they adhere to the specific codes of conduct. These labelling schemes are often run by NGOs and local governments. To be able to run a labelling scheme, this requires strict reinforcement of the guidelines that have been set in the code of conduct, which does subsequently make the label of good practice more credible (Lissner & Mayer, 2020). However, in order to be effective, both tourism operators and tourists have to be educated so that they understand that operators carrying that particular label are improving their behaviour and why this is critical. Only then will tourists be motivated to choose operators with such a label and motivate other operators to join (Mallard, 2019). Finally, there are some individual management tools that can be implemented to reduce the effects of tourism such as limiting the disturbance to a certain time of day or area and establishing area closures (Hoyt, 2007).

3.2.4 Whaling activities

The only country that still carries out legal whaling activities in the WCR is St Vincent and the Grenadines (Fielding, 2018 ; Stevick et al., 2018). According to the IWC, whaling has been deemed an important part of the culture on St Vincent and is therefore permitted to a certain extent (Firestone & Lilley, 2005). The only species they are legally able to catch is the humpback whale, but there have been reports of illegal take of other species of whale in the last 40 years. Between the years 1986 and 2020, a total of 48 humpback whales have been taken by St Vincent (Fielding & Kiszka, 2021 ; IWC, 2020). A review on the artisanal and Aboriginal Subsistence Whaling in St Vincent by Fielding & Kiszka in 2021 found that more than 13.500 small cetaceans had been killed in the period 1949-2017, which included short-finned pilot whales. There is limited research on which other countries in the WCR are undertaking these activities (Fielding, 2021).

3.2.4.1 Whaling activities: mitigation measures

The most well-known measure that has been taken against whaling activities is the moratorium on commercial whaling, established in 1986 by the IWC. All members of the IWC were obliged to adhere to this moratorium. Not all Caribbean countries chose to become members of the IWC, but St Vincent and the Grenadines has been a member since the 1990s. Although the hunting of larger cetaceans is controlled by the IWC under the Aboriginal Subsistence Whaling Act, they have no control over smaller cetaceans (Gillespie, 2003). Small cetacean task teams have been established in recent years but tend to focus on species that are extremely vulnerable and at risk of extinction. Therefore, no measures are taken by the IWC to prevent smaller cetaceans from being hunted (IWC, 2020). The IWC does however establish catch quotas for larger species and has designated certain areas as ocean sanctuaries where whales may not be hunted if the moratorium were to be lifted (IWC, 1946).

3.2.5 Marine litter

Marine litter is found all over the world, with the WCR being no exception. A review by do Sul & Costa in 2007 indicated that most marine litter in the WCR consists of packaging, plastic bags, discarded fishing gear and other single use plastics. The primary issue being that the WCR lacks in proper marine and land-based waste management. Marine litter can cause an array of afflictions in marine mammals via entanglement and ingestion. Entanglements can be the cause of the direct mortality via drowning or suffocation, while ingestion often leads to blockages in the digestive tract which can eventually result in death (Katsanevakis, 2008). The ingestion of plastics can also lead to toxic additives being absorbed into their tissue, which can affect their ability to reproduce, their growth rates, and lead to disease (Andrady, 2011). It has been found that 56% of all species of cetacean occasionally ingest plastics and that 28-31% occasionally become entangled in marine litter (Baulch & Perry, 2014; Kühn et al., 2015). In most cases of entanglement, the cetacean has been caught in discarded or lost fishing gear.

Out of the four species studied, frequent entanglements have been observed for the humpback whale and the common bottlenose dolphin. It is suggested that all species of cetacean might be at risk of ingesting plastics, however, this has only been frequently observed for the common bottlenose dolphin, short-finned pilot whale, and sperm whale (Baulch & Perry, 2014). Although afflictions due to ingesting or becoming entangled in plastics have been documented to a certain extent for almost all species of cetacean in the last 30 years, it has proven more difficult to document the effects of microplastics. However, some studies have been able to identify microplastics in the digestive tract of the bottlenose dolphin and the humpback whale by Lusher et al. in 2018 and Besseling et al. in 2015. Although the effects of marine plastic litter on cetaceans are well-studied, the scope of the threat remains unclear (Zantis et al., 2021). There are no specific statistics regarding this issue for the WCR.

3.2.5.1 Marine litter: mitigation measures

The most important mitigation measures that are currently being implemented in some countries are the banning of single use plastics and needing to pay for plastic bags. A study by Herberz et al. in 2020, assessing the sustainability outcome of banning single use plastics, found that a worldwide ban would decrease the marine plastic pollution by 5.5%. Although this measure would only reduce the plastic issue by quite a small percentage, it is perceived as an effective measure as it also creates awareness (Rhein & Schmid, 2020). The partial solution that banning single use plastic would create should be supplemented by a worldwide tax on plastic bag use. In 2018, Schnurr et al. found that a worldwide tax on plastic bags would reduce bag use by 33-96%. Currently, there are 127 countries that have either banned or have instituted taxes for the use of plastic bags and 56 countries have either banned or have instated taxes on all or some types of single use plastics. In addition, a total of eight countries have banned the use of microbeads since 2018 (United Nations Environment Programme, 2018).

Plastic pollution not only consists of containers and bags, but also of abandoned fishing gear. There are multiple measures that are taken internationally to mitigate the effects of abandoned fishing gear on the marine environment, especially cetacean entanglements (Gulland et al., 2018). The first measure consists of marking fishing gear with either a label of ownership or GPS tracking so that owners can be identified in the hope that willingly abandoning fishing gear becomes disincentivised (Gilman, 2015; MacMullen et al., 2003). Other measures include restrictions regarding the fishing effort per piece of fishing gear, establishing a ban on the discarding and intentional abandonment of fishing gear, and providing incentives to reduce abandonment and discarding (MacMullen et al., 2003; NAFO, 2018). These incentives can consist of mandatory deposits on new fishing gear, which will only be returned when unwanted fishing gear has been handed in and creating port facilities at which unwanted fishing gear can be easily handed in (Gilman et al., 2016).

3.2.6 Underwater noise

Anthropogenic underwater noise is produced by a range of activities. Although nearly all marine wildlife is susceptible to anthropogenic noise, cetaceans seem to be particularly affected as they are dependent on sound for practically all aspects of their lives (Weilgart, 2007). The reactions that have been linked to anthropogenic noise include changes in vocalizations, avoidance and shifts in migration, strandings, hearing damage, and stress that may be lethal (Garside, 2019 ; Weilgart, 2007). In the past 50 years, noise produced by vessels alone has increased by 32-fold, including shipping and recreational vessels (Duarte et al., 2021). Vessels mainly produce low frequency noise, which can travel farther than higher frequencies and may even be heard over millions of square metres from the source (Weilgart, 2007). It is said that cetaceans are more sensitive to these low sound frequencies, due to their long carrying distance (Park et al., 2017).

The Caribbean is highly dependent on marine traffic for the import of their materials and products. As mentioned before, anthropogenic underwater noise can be cause by an array of activities, another one of them being drilling for gas and oil. A study by Farmer et al., 2018 found that consistent exposure to noise produced by drilling activities led to permanent disturbances in foraging behaviour and reduced the fitness of female sperm whales, leading to starvation and unsuccessful pregnancies. There is some controversy regarding the extent to which underwater noise has effects on cetaceans, as the effects of and the reactions to this threat differ per species. Moreover, the effects of anthropogenic underwater noise have not yet been fully examined for all species, as this must be done in controlled environments to be able to obtain consistent data (Farmer et al., 2018).

3.2.6.1 Underwater noise: mitigation measures

The effects of underwater noise can be mitigated by several different measures depending on the activity that is being executed. Negative effects from coastal or offshore construction can for example be reduced by only carrying out these activities at certain times of day or outside of breeding seasons (Jefferson et al., 2009). Several measures can also be taken to reduce the amount of underwater noise that is projected from construction or certain drilling activities. One of these measures is to create a bubble curtain. This measure involves creating an air bubble curtain around the source of the activity. These bubbles then impede sound transmissions by reflecting and absorbing the sound waves (Causer, 2018). A study by Bellman in 2014 found that bubble curtains can reduce anthropogenic noise by 10-18 dB and are deemed as suitable to mitigate offshore underwater noise. Some other measures include the acoustic decoupling of noisy construction equipment, by placing the equipment onto foam mats or rubber wheels, instead of onto the steel hulls of vessels and barges (Jefferson et al., 2009).

3.2.7 Oil and contaminants

The release of oil and other chemical pollutants, such as PCBs and heavy metals, can have harmful and long-lasting effects on the marine environment (Peterson et al., 2003). Many of these chemical pollutants can bioaccumulate in cetaceans through ingestion, inhalation, or skin exposure. Exposure to these chemicals can have toxic effects and they are a potential threat to cetacean stocks (Edema, 2012). After the Deepwater Horizon Oil Spill in 2010, 101 cetacean carcasses were found and it is estimated that this represented only up to 6.2% of cetacean deaths caused by this event (Williams et al., 2011). Following the 'Exxon Valdez' oil spill, one of the largest of its kind, a study by Matkin et al. in 2008 found that a population of killer whales had not recovered to pre-spill numbers 16 years after the spill.

The WCR holds approximately one fifth of the world's oil reserves and many Caribbean countries have a large offshore oil production sector, increasing the chance of a pollution event occurring (Solano et al., 2021). Oil spills are a significant source of marine pollution, but an even bigger source of chemical pollutants is maritime traffic. A 2007 study by the Joint Group of Experts on the Scientific Aspects of Marine Protection, found that 51% of marine oil pollution is caused by maritime traffic. The WCR holds one of busiest maritime trafficways in the world, which also significantly increases the chance of oil and chemical pollution events occurring (Singh et al., 2015).

3.2.7.1 Oil and contaminants: mitigation measures

Each country takes their own precautions and measures when dealing with drilling and transportation of oil and waste disposal. However, some NGOs or governing bodies have devised contingency plans in case of accidental marine pollution. These contingency plans, drawn up to ensure organised responses to significant events, usually contain guidelines for the transportation of equipment and which equipment is needed, proper animal care, data collection, and guidelines for animal disposal (Baker et al., 2008). The most important part of any contingency plan is to make sure proper training is given to any that will be involved in caring for contaminated animals and that will have to make decisions regarding an animals welfare and further course of action (Fingas, 2001).

3.2.8 Climate change

Climate change is causing rises in seawater temperature, extreme weather events and a higher level of acidification (Meesters et al., 2010). Due to the changing chemical and physical characteristics of marine waters, ranges of cetacean prey are shifting, causing negative consequences for the feeding patterns and distribution of cetaceans (Simmonds & Elliot, 2009). Furthermore, climate change can have an effect on community structure and increase the susceptibility to diseases (Learmonth et al., 2006). There has been evidence that suggests the change of migration patterns and abundance of cetaceans due to climate change (Lambert et al., 2010).

3.2.8.1 Climate change: mitigation measures

Almost all countries have measures in place to mitigate the effects of climate change. Through habitat restoration, rewilding, reducing outputs of CO_2, and investing in renewable energy, some of the effects of climate change can be reduced (Duarte et al., 2020; Malhi et al., 2020) However, cetaceans will have undoubtedly already responded to the changing environment (van Weelden et al., 2021). Therefore, it is important to not only take measures to reduce the effects of climate change but also to revise existing and take new measures to protect cetaceans that have been affected by the consequences of climate change. These measures include expanding existing migration corridors and protected zones and to designate new areas as protected in order to accommodate changes in distribution (Grose et al., 2020).

3.2.9 Habitat degradation

All the above-mentioned threats contribute to habitat degradation, which in time exasperate the vulnerability of cetaceans worldwide. However, there are a few mitigation measures that can reduce degradation and loss of suitable habitat.

3.2.9.1 Habitat degradation: mitigation measures

One of the most common measures countries take to protect marine life is to establish Marine Protected Areas (MPAs). There are many types of MPAs all over the world, each with their own function and set of measures, as defined by the governing body. According to the IUCN, these protected areas can be categorised into six management categories. Areas aimed at protecting cetaceans often fall under category IV: Habitat/Species Management Area. However, fishing and other human activities are often still permitted (Dudley et al., 2010). Currently, 7.92% of the oceans is either fully or partially protected. Out of this percentage, less than half is fully protected against human impact through banning fishing activities and limiting human visitation (Marine Protection Atlas, 2021; Protected Planet, 2021).

In order to help identify which areas are important for marine mammals and should therefore be protected, the Marine Mammal Protected Area Task Force has developed a tool that determines whether an area meets marine mammal habitat criteria. The criteria on which an area is evaluated can be divided into four categories; species vulnerability, distribution and abundance, key life cycle activities, and special attributes, which considers the uniqueness of an area (MMPATF, 2021). If all criteria are met, it is deemed as an Important Marine Mammal Area (IMMA). The presence of certain threats, such as fishing activities, whale watching or whale harassment, vessel strikes, military exercises, and research methods and offshore industry that could be harmful, is also taken into account (Polidoro et al., 2012).

An area which has been designated as an IMMA is not yet officially protected but can assist in establishing new MPAs and extending existing MPAs and therefore only serves as an indication of an area of importance (Carlucci et al., 2021). Furthermore, by identifying which areas are most important to marine mammals, these areas can be prioritised when drawing up contingency plans for oil spills and legislation for mammal bycatch and underwater noise (MMPATF, 2021). Currently, 24 IMMAs have been established and 158 areas have the potential to become an IMMA (MMPATF, 2020).

3.2.9.2 Habitat degradation: mitigation through research and education

Scientific research into cetacean behaviour is proving to be extremely useful in forming new management measures and implementing correct existing measures. One of the research techniques used to assess population sizes and study behavioural aspects of cetaceans is through aerial monitoring (Nowacek et al., 2016). With the rising popularity of drones, or unmanned aircrafts, the ability to track cetaceans and observe their behaviour could even be increased through the general public (Pirotta et al., 2019). For cetacean research, including the general public not only increases the amount of data that can be collected but also provides an opportunity to educate the public on the need for improved cetacean conservation (Currie et al., 2018 ; McKinley et al., 2017). In addition, some organisations even train individuals of the public to become observers or train them to be able to use a certain method needed to validate the data that is being collected.

3.3 Threats in the Yarari Sanctuary

There is no evidence that whaling activities and whale watch tours are being carried out within the Yarari Sanctuary. Although data is severely limited, vessel activity is thought to be a threat in the sanctuary, as high occurrence of vessels is also present within the sanctuary borders (as seen in Figure 3.2.2). The data for fishing pressure assumes that there is no direct threat of fishery interaction for cetaceans. As the effects of climate change can be seen all over the world, it is thought that the Yarari Sanctuary is no exception to the negative effects of a changing climate. However, the extent to which climate change is affecting the cetaceans that reside in the sanctuary is unclear. In addition, there are no statistics regarding issues of pollution in the sanctuary. However, as vessel activity is relatively high and all forms of pollution tend to travel beyond their point of origin, it is likely that the Yarari Sanctuary is subject to different types of pollution (Duarte et al., 2021; Rhein & Schmid, 2020). Overall, there is not enough research conducted and data available to be able to establish which threats occur in Yarari and if there are any threats if these are a threat to the specific species.

3.3.1 Mitigation measures

Currently, there are no specific policies in place for cetacean protection in the Yarari Sanctuary, but there are a number of laws that have been drawn up for Saba, Bonaire, and St. Eustace. One of these laws, the Visserijwet BES, states that it is prohibited to carry out fishing activities without proper equipment and under certain circumstances. The requirements that are mentioned in this law require fishermen to use appropriate mesh sizes and nets, to refrain from using bait consisting of sharks or rays, and to refrain from using explosives and chemicals. In addition, accidental bycatch is to be placed back into the ocean immediately, dead or alive, and has to be relocated in such a way that increases their chance of survival (Overheid, 2021). A second law regarding response to oil spills has been put in place on Bonaire and St. Eustace. However, the equipment the island has for handling these oil spills, is not sufficient for large spills (Meesters et al., 2010).

Thirdly, it is prohibited by law to hunt cetaceans in the waters surrounding these islands. Saba was designated as a Particularly Sensitive Sea Area (PSSA) in 2012, which entails that specific measures can be used to control maritime activities. Protective measures regarding no-anchoring zones and Areas To Be Avoided (ATBA) for large ships were implemented under this designation (Meesters et al., 2010; DCNA, 2013). Lastly, as part of the Cartagena Convention, the SPAW-protocol has been signed by the Netherlands Antilles, stating that rare and fragile ecosystems and habitats must be protected, thereby protecting the endangered and threatened species residing in them (Meesters et al., 2010).

4 Discussion

The primary goal of this report was to examine which conservation measures the Dutch Caribbean can implement to protect cetaceans residing in and passing through the Yarari Sanctuary. There are a variety of measures that can be taken to mitigate the effects of certain threats, but some have proven to be less effective for certain species. In addition, findings from literary sources and interviews, suggest that the current data on the temporal and geographical distribution of the cetacean species might not be accurate. The obtained data indicated that most cetaceans were sighted near shore and in the middle of the WCR. However, it is likely that these data are biased as the data were mainly obtained through research institutes located on the shores of the United States. It is therefore expected that observers are more likely to report a cetacean sighted nearer to shore, and less so in open waters. It is also expected that shipping vessels, cruise ships, and tourists do not frequently report cetacean sightings, and if they do, it is unknown whether the exact species of cetacean was determined in all cases. In addition, various research institutions (NMFS, SEFSC, MMC) along the Gulf of Mexico are currently researching sperm whales and bottlenose dolphins, which further indicates the possibility of biased results (Cornish, 2015).

The overview of species sighted in the Yarari Sanctuary, suggests that all four species prefer to remain near coastal regions rather than in open waters. However, this overview is likely to be incomplete, as the data are solely based on sightings. Based on information obtained through interviews, it is clear that there is a lack of research on the distribution of cetaceans in the WCR, and thus the Yarari Sanctuary (T. Bervoets, personal communication, 3 December 2021; J. Bernus, personal communication, 7 December 2021; D. Debrot, personal communication, 16 December 2021). One expert quoted that monitoring and identifying cetaceans is often difficult and imprecise, and that lack of and incorrect species identification leads to data with poor quality (D. Debrot, personal communication, 16 December 2021). Nevertheless, data suggests that all four species of cetacean are known to reside in or pass through the Yarari Sanctuary and could therefore be exposed to multiple threats.

It is expected that the intensity of fishing pressure is low within the Yarari Sanctuary. Restrictions of fishing activities and certain gear types, under the Visserijwet BES, imply that there is limited risk of entanglement and being caught as bycatch for all four species when residing in the sanctuary. Although the intensity of the threat is expected to be low, there is no scientific evidence that substantiates this expectation. Reasons for the lack of data could be due to an overall lack of research, and to low recovery rates of cetacean carcasses due to western currents (J. Couvat, personal communication, 15 December 2021; D. Debrot, personal communication, 16 December 2021). This indicates that the actual risk is possibly being underestimated because of the current absence of data. Although there is no evidence to suggest that fishing activity poses a threat to species within the sanctuary, this does not mean that preventative measures should not be taken to mitigate effects of threats that travel beyond their origin points, such as entanglement in fishing nets. An effective way of preventing this is to create legislation under which it is compulsory to mark fishing gear with owner labels or GPS trackers. This ensures that discarding fishing gear or absent attempts of retrieving lost fishing gear is reduced, as executors can be identified and fined (Gilman, 2015; MacMullen et al., 2003). Fishermen who cooperated in a pilot project for marking fishing gear, set up in Indonesia, were supportive and enthusiastic about this concept (Global Ghost Gear Initiative, 2019).

Besides threats of becoming entangled in fishing gear, other types of pollutants like oil contaminants, plastics, and underwater noise are thought to pose a threat to cetaceans residing in and passing through the Yarari Sanctuary. As a large amount of oil drilling occurs in the WCR, the occurrence of an oil spill is not unlikely and would affect all four species of cetacean focussed on in this report. Because the existing oil spill contingency plans are outdated and their equipment insufficient, an oil spill could have huge ecological consequences (Meesters et al., 2010). An appropriate mitigation measure would be to update these plans, obtain adequate equipment, and share these plans with remaining islands and bordering countries. Due to the fact that most Caribbean countries do not have proper waste disposal management, plastic pollution is thought to be an issue in both the WCR and in the Yarari Sanctuary. The most effective measure to reduce the amount of plastics in the marine environment would be to ban or tax single use plastics. Not only will this measure increase awareness, but in time, it is expected to significantly reduce the amount of single use plastics in the environment (Herberz et al., 2020; Rhein & Schmid, 2020). However, to have every country cooperate with this measure and implement it will be a big task and maybe unrealistic on the short term. Therefore, a starting point could be to set up organizations that clean up along the coast and streets.

Anthropogenic underwater noise, caused by offshore construction and vessels, is a threat to all four species of cetacean that occur in the Yarari Sanctuary. The most effective measure that can be taken to mitigate the effects of noise pollution, is to restrict construction during breeding and birthing seasons to ensure juvenile cetaceans make it through their first years. Use of bubble curtains has proven to be effective, but the implementation of this measure would be expensive, and further research needs to be conducted into the level of mitigation that this measure provides (Dähne et al., 2017). A second important cause of underwater noise pollution is the presence of vessels. The most common mitigation measure used to reduce the effects of underwater noise originating from vessels is to implement speed restrictions. It is expected that this measure might be difficult, as enforcement is likely to be economically challenging (Silber et al., 2014).

Vessels do not only pose a threat to cetaceans due to the production of underwater noise, but also due to possible collisions with vessels. There is an array of measures that can be taken to help prevent vessel strikes, the most obvious one being implementation of speed restrictions. Another effective measure would be to have trained observers onboard. However, training observers is not perceived as cost-effective, and it is expected that the unfeasibility of this measure will stop it from being implemented correctly (Wiley et al., 2016). Acoustic deterrent devices are known to limit interaction between vessels and cetaceans, however, this technique is not effective for all types of cetacean and cetaceans can become habituated to these devices (Schoeman et al., 2020). In addition to limiting cruising speeds, redirection of shipping lanes has proven to be one of the most mitigating measures in ensuring reduction of vessel strikes. However, the redirecting of shipping lanes may be more difficult to implement as there are a lot of stakeholders involved, therefore reducing speed may be a better option for the short term.

Climate change and ultimately habitat degradation pose major threats to cetaceans worldwide, the Yarari Sanctuary being no exception. To mitigate these negative effects, creating more MPAs could improve health and promote survival in cetaceans. A study by Purdon et al (2020) compared the effects of anthropogenic stressors between different designated areas, including a number of MPAs, along the coast of South Africa. The effects and number of anthropogenic stressors were found to be considerably lower within most MPAs, which indicates that MPAs can offer protection from anthropogenic impact. However, this study stresses the fact that for MPAs to be effective, management needs to be in place. As there are no current management measures in place for the Yarari Sanctuary, it is essential that effective management of the MPA is implemented. In addition, creating corridors by connecting MPAs is expected to decrease habitat degradation and expand areas with low anthropogenic impacts (Johnson et al., 2022). This so-called connectivity conservation has already been applied in terrestrial ecosystems and is becoming increasingly popular amongst marine conservationists (Allan et al., 2021). As the Yarari Sanctuary is currently comprised on two disjunct areas, it would be highly beneficial to create a corridor to promote habitat connectivity.

Although the Yarari Marine Mammal Sanctuary MPA was established in 2015, there have been limited efforts to research and implement a management strategy, which renders the designation void. In addition, there are no collaborative efforts between neighbouring islands to collect the required data (J. Bernus, personal communication,7 December 2021). Overall, the limiting factor for this research is the reoccurring issue of data deficiencies in the Yarari Sanctuary. As little is known about the anthropogenic pressures and the distribution of cetaceans within the sanctuary, it is difficult to establish a management plan specific to the area. Most research is based on the WCR and not specifically on the Yarari Sanctuary, which is the main reason for lack of specific management measures within the sanctuary. This means that management recommended in this report is based on data regarding the WCR. In addition, these data are often outdated, preceding the establishment of the sanctuary. These issues should be acknowledged for future research, taking into account that these issues need to be resolved through extensive research before a detailed management plan can be created for the Yarari Sanctuary.

5 Conclusion

The aim of this research was to examine what conservation measures the Dutch Caribbean can take to protect cetaceans, specifically the humpback whale, sperm whale, short-finned pilot whale and common bottlenose dolphin, residing in and around the Yarari Sanctuary, to reduce the effects of threats from anthropogenic origin. The Yarari Sanctuary does not yet have an established plan for cetacean conservation. However, there are a few policies and laws that apply to the sanctuary. One of these policies is the Visserijwet BES, which involves restrictions for fishing gear. Furthermore, it is prohibited to hunt cetaceans within the sanctuary and the sanctuary has been designated as a Particularly Sensitive Sea Area under the Cartagena Convention in 2012. The final policy that is currently implemented in the Yarari Sanctuary, is an oil spill contingency plan. The main finding of this report is the significant lack of data for the Yarari Sanctuary, which subsequently impairs the development of effective management strategies. Based on information obtained for the Wider Caribbean Region, recommendations can be made to mitigate the effects of anthropogenic threats that are likely to be present in the sanctuary. However, it is uncertain whether these recommendations are all relevant to the current situation.

According to distribution maps, the four species of cetacean are rarely present within the sanctuary, with only a few sightings along the coasts of the bordering islands. This presents challenges in determining whether species will be affected by a certain threat within the sanctuary. Based on findings from databases and interviews, likely conclusions can be made regarding the intensity and occurrence of threats and the mitigation measures for these threats in the Yarari Sanctuary. The threat of fisheries interactions is presumed low within the sanctuary, which indicates no further actions need to be taken to mitigate the effects of this theat. Similarly, the intensity and occurrence of vessel strikes is also presumed to be low but not absent near Saba and St. Eustace. Therefore, implementation of speed restrictions and redirection of shipping lanes is recommended. Threats for which intensity and occurrence are expected to be high, are all types of pollution, i.e. plastic, oil and chemical, and underwater noise. To mitigate the effects of plastic pollution, a ban or tax on single use plastics would be the most effective way to reduce the amount of plastic in the environment. In addition, pollution through discarded fishing gear can be avoided by marking fishing gear with ownership labels or GPS trackers, so that guilty parties can be identified and fined.

Threats of oil and chemical spills can be mitigated through implementation of well-developed contingency plans that are adopted by all surrounding countries. The most feasible solution to underwater noise pollution are seasonal closures. Lastly, the effects of climate change and habitat degradation can be mitigated by maintaining existing and creating new MPAs and by connecting these with corridors. Although this report gives an overview of possible threats in the Yarari Sanctuary, the most important finding remains to be the data deficiency within this area. In conclusion, this report outlines a larger issue than lack of management strategy, that being the lack of research to substantiate a management plan. Nevertheless, this report can be used as a starting point to determine priorities for future research and management.

5.1 Recommendations

Based on these findings, it is highly recommended that further data is collected in order to formulate more accurate advice on what measures should be taken to protect cetaceans in the Yarari Sanctuary. The first step would be for research institutes to compile all available data into a collaborative data set, that is accessible to all neighboring countries of the sanctuary. Future research should consist of tracking and tagging of cetaceans and the collection of data on bycatch, entanglements, and vessel strike rates, and pollution intensity and composition. On the short term it is advised to start with tagging cetaceans to monitor their movement, this way specific locations can be allocated for further research and data collection on the above-mentioned threats. This research needs be long-term, at least 5-10 years, as some species of cetacean are not present year-round. As 5-10 years is a long time to wait, it is recommended that the management measures that have been described in this report, based on information on the WCR, are assessed on the political and economic feasibility of these measures and, where possible, temporarily implemented. Additional research carried out in the next years can then aid in specifying this management plan to more suit the current situation.

An important future step is to include the general public in conservation practices through citizen science. Workshops for the local community, fishermen and skippers can be a good way to create awareness and to teach people how to deal with certain situations. Working with local fishermen to gather data and implementing simple monitoring programmes could further help to obtain data regarding entanglements and bycatch. Other situations can include reporting of and dealing with entanglements, vessel strikes, cetacean carcasses, and floating marine litter. Furthermore, extensive research should be conducted into the effects of (micro)plastics on the marine environment and into range shifts in prey. It is advised to adopt a reporting platform to promote universal use and to ensure standardized collection of data. In addition, it is highly recommended that all countries bordering the WCR are involved in the research that is being conducted, and that information is shared. Lastly it is a task for the government to implement proper marine and land-based waste management and to focus on measures countries can take to protect cetaceans from the growing effects of climate change.

References

Allan, J. C., Beazley, K. F., & Metaxas, A. (2021). Ecological criteria for designing effective MPA networks for large migratory pelagics: Assessing the consistency between IUCN best practices and scholarly literature. *Marine Policy*, *127*, 104219.

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine pollution bulletin*, *62*(8), 1596-1605.

Azungah, T. (2018). *Qualitative research: deductive and inductive approaches to data ` analysis.* Qualitative Research Journal vol. 18 No. 4, pp. 383-400.

Baker, T. L., Jeansonne, J., Henry, C., & Tarpley, J. (2008). NOAA OFFICE OF RESPONSE AND RESTORATION'S ROLE DURING OIL SPILLS WHERE MARINE MAMMALS ARE INVOLVED. In *International Oil Spill Conference* (Vol. 2008, No. 1, pp. 991-994). American Petroleum Institute.

Barragán-Barrera, D. C., Luna-Acosta, A., May-Collado, L. J., Polo-Silva, C. J., Riet-Sapriza, F. G., Bustamante, P., ... & Caballero, S. (2019). Foraging habits and levels of mercury in a resident population of bottlenose dolphins (Tursiops truncatus) in Bocas del Toro Archipelago, Caribbean Sea, Panama. *Marine pollution bulletin*, *145*, 343-356.

Baulch, S., & Perry, C. (2014). Evaluating the impacts of marine debris on cetaceans. *Marine pollution bulletin*, *80*(1-2), 210-221.

Bellmann, M. A. (2014). Overview of existing noise mitigation systems for reducing pile-driving ` noise. *Proceeding auf der Internoise*.

Besseling, E., Foekema, E. M., Van Franeker, J. A., Leopold, M. F., Kühn, S., Rebolledo, E. B., ... & Koelmans, A. A. (2015). Microplastic in a macro filter feeder: humpback whale Megaptera novaeangliae. *Marine pollution bulletin*, *95*(1), 248-252.

BioNews18. (2015). *Yarari Sanctuary established.* Retrieved October 26, 2021, from https://dcnanature.org/yarari-sanctuary-established-bionews/

Bjorkland, R. H. (2011). An assessment of sea turtle, marine mammal and seabird bycatch in the Wider Caribbean Region. PhD Dissertation, Department of Environment, Duke University. 230 pp.

Bristow, L. A., Mohr, W., Ahmerkamp, S., & Kuypers, M. M. M. (2017). *Nutrients that limit growth in the ocean*. Current Biology, 27(11), 474-478.

Brotons, J. M., Munilla, Z., Grau, A. M., & Rendell, L. (2008). Do pingers reduce interactions between bottlenose dolphins and nets around the Balearic Islands?. *Endangered Species Research*, *5*(2-3), 301-308.

Carlucci, R., Manea, E., Ricci, P., Cipriano, G., Fanizza, C., Maglietta, R., & Gissi, E. (2021). Managing multiple pressures for cetaceans' conservation with an Ecosystem-Based Marine Spatial Planning approach. *Journal of Environmental Management*, *287*, 112240.

Causer, A. (2018). Air bubble curtain for windfarm construction. *Maritime Journal*. Retrieved January 18, 2022, from https://www.maritimejournal.com/news101/marine-civils/marine-civils/air-bubble-curtain-for-windfarm-construction

CLME Project. (2013). The Strategic Action Programme for the Sustainable Management of the Shared Living Marine Resources of the Caribbean and North Brazil Shelf Large Marine Ecosystems (CLME+ SAP). 99 pp.

Cook, D., Malinauskaite, L., Davíðsdóttir, B., Ögmundardóttir, H., & Roman, J. (2020). Reflections on the ecosystem services of whales and valuing their contribution to human well-being. *Ocean & Coastal Management*, *186*, 105100.

CRRU. (n.d.-a). Humpback whale. Retrieved January 14, 2022, from http://www.crru.org.uk/humpback.asp

CRRU. (n.d.-b). Bottlenose dolphin. Retrieved January 14, 2022, from http://www.crru.org.uk/bottlenose_dolphin.asp

Currie, J. J., Stack, S. H., & Kaufman, G. D. (2018). Conservation and education through ecotourism: Using citizen science to monitor cetaceans in the four-island region of Maui, Hawaii. *Tourism in Marine Environments*, *13*(2-3), 65-71.

Dähne, M., Tougaard, J., Carstensen, J., Rose, A., & Nabe-Nielsen, J. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. *Marine Ecology Progress Series*, *580*, 221-237.

DCNA. (2013). SABA bank gains PSSA status. Retrieved January 30, 2022, from https://dcnanature.org/saba-banks-pssa-status-fully-implemented/

Debrot, A. O., Tamis, J. E., de Haan, D., Scheidat, M., & van der Wal, J. T. (2017). *Priorities in*

management implementation for marine mammal conservation in the Saba sector of the Yarari Sanctuary (No. C097/17). Wageningen Marine Research.
Debrot, A. O., Witte, R. H., & Scheidat, M. (2011). *The marine mammals of the Dutch Caribbean: a comparison between EEZ sectors, contrasts and concerns.* IMARES Wageningen UR, 93.
Do Sul, J. A. I., & Costa, M. F. (2007). Marine debris review for Latin America and the wider Caribbean Region: from the 1970s until now, and where do we go from here?. *Marine Pollution Bulletin*, *54*(8), 1087-1104.
Doughty, C. E., Abraham, A., & Roman, J. (2020). The sixth R: Revitalizing the natural phosphorus pump.
Doughty, C. E., Roman, J., Faurby, S., Wolf, A., Haque, A., Bakker, E. S., Malhi, Y., Dunning Jr, J.B., & Svenning, J. C. (2016). *Global nutrient transport in a world of giants.* Proceedings of the National Academy of Sciences, 113(4), 868-
Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J. P., ... & Worm, B. (2020). Rebuilding marine life. *Nature*, *580*(7801), 39-51.
Duarte, C. M., Chapuis, L., Collin, S. P., Costa, D. P., Devassy, R. P., Eguiluz, V. M., ... & Juanes, F. (2021). The soundscape of the Anthropocene ocean. *Science*, *371*(6529).
Dudley, N., Parrish, J. D., Redford, K. H., & Stolton, S. (2010). The revised IUCN protected area management categories: the debate and ways forward. *Oryx, 44*(4), 485-490.
Durfort, A., Mariani, G., Troussellier, M., Tulloch, V., & Mouillot, D. (2021). The collapse and recovery potential of carbon sequestration by baleen whales in the Southern Ocean.
EEA. (2016). Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. EEA Report No 1/2017. https://doi.org/10.2800/66071.
Edema, N. (2012). Effects of crude oil contaminated water on the environment. *Crude oil emulsions–composition stability and characterization*, 169-180.
Eklöf, J. S., Sundblad, G., Erlandsson, M., Donadi, S., Hansen, J. P., Eriksson, B. K., & Bergström, U. (2020). A spatial regime shift from predator to prey dominance in a large coastal ecosystem. *Communications biology*, *3*(1), 1-9.
FAO Fisheries Department. (2014). The Sustainable Intensification of Caribbean Fisheries and Aquaculture. Retrieved January 17, 2022, from https://www.fao.org/3/i3932e/i3932e.pdf
Farmer, N. A., Baker, K., Zeddies, D. G., Denes, S. L., Noren, D. P., Garrison, L. P., ... & Zykov, M. (2018). Population consequences of disturbance by offshore oil and gas activity for endangered sperm whales (Physeter macrocephalus). *Biological conservation*, *227*, 189-204.
Fielding, R., & Kiszka, J. J. (2021). Artisanal and Aboriginal Subsistence Whaling in Saint Vincent and the Grenadines (Eastern Caribbean): History, Catch Characteristics, and Needs for Research and Management. *Frontiers in Marine Science*, *8*, 397.
Fielding, R. (2018). *The Wake of the Whale*. Harvard University Press.
Firestone, J., & Lilley, J. (2005). Aboriginal subsistence whaling and the right to practice and revitalize cultural traditions and customs. *Journal of International Wildlife Law & Policy*, *8*(2-3), 177-219.
Flynn, K. R., & Calambokidis, J. (2019). Lessons from placing an observer on commercial cargo ships off the US West coast: utility as an observation platform and insight into ship strike vulnerability. *Frontiers in Marine Science*, *6*, 501.
Franklin, T., Franklin, W., Brooks, L., Harrison, P., Pack, A. A., & Clapham, P. J. (2021). Social Behaviour of Humpback Whales (Megaptera novaeangliae) in Hervey Bay, Eastern Australia, a Preferential Female Stopover During the Southern Migration. *Frontiers in Marine Science*.
Garcia Cegarra, A. M., Castro, C., & Van Waerebeek, K. (2021). Feeding of humpback whales in low latitues of the Southeast Pacific Ocean. *Neotropical Biodiversity, 7*(1), 421-430.
Garside, M. (2019b). Number of offshore rigs worldwide 2018 by region. Accessed on 24 September2019, from https://www.statista.com/statistics/279100/number-of-offshorerigs-worldwide-by-region/
Gazo, M., Gonzalvo, J., & Aguilar, A. (2008). Pingers as deterrents of bottlenose dolphins interacting with trammel nets. *Fisheries Research*, *92*(1), 70-75.
Gero, S., and Whitehead, H. (2016). Critical Decline of the Eastern Caribbean Sperm Whale Population. PLoS ONE 11(10), e0162019. https://doi.org/10.1371/journal.pone.0162019
Gillespie, A. (2003). Small cetaceans, international law and the International Whaling Commission. In *The future of cetaceans in a changing world* (pp. 217-282). Brill Nijhoff.
Gilman, E. (2015). Status of international monitoring and management of abandoned, lost and discarded fishing gear and ghost fishing. *Marine Policy, 60,* 225-239.
Gilman, E., Chopin, F., Suuronen, P., & Kuemlangan, B. (2016). Abandoned, lost and discarded gillnets

and trammel nets: methods to estimate ghost fishing mortality, and the status of regional monitoring and management. *FAO Fisheries and Aquaculture Technical Paper*, (600), I.
Global Ghost Gear Initiative. (2019). Gear marking in Indonesian small-scale fisheries: a Pilot Project Case Study Global Ghost Gear Initiative, 4pp. DOI: http://dx.doi.org/10.25607/OBP-1682
Grose, S. O., Pendleton, L., Leathers, A., Cornish, A., & Waitai, S. (2020). Climate change will re-draw the map for marine megafauna and the people who depend on them. *Frontiers in Marine Science*, *7*, 547.
Gulland, F. M., Dierauf, L. A., & Whitman, K. L. (Eds.). (2018). *CRC handbook of marine mammal medicine*. CRC Press.
Heenehan, H., Stanistreet, J. E., Corkeron, P. J., Bouveret, L., Chalifour, J., Davis, G. E., ... & Van Parijs, S. M. (2019). Caribbean Sea soundscapes: Monitoring humpback whales, biological sounds, geological events, and anthropogenic impacts of vessel noise. *Frontiers in Marine Science*, *6*, 347.
Herberz, T., Barlow, C. Y., & Finkbeiner, M. (2020). Sustainability assessment of a single-use plastics ban. *Sustainability*, *12*(9), 3746.
Hoyt, E. (2007). A blueprint for dolphin and whale watching development. *Humane Society International*.
IMO. (2014). Implications of the United Nations convention on the law of the sea for the International Maritime Organization. *Vol.LEG/MISC,7.*
IUCN. (2021). *The IUCN red list of threatened species*. Retrieved October 12, 2021, from https://www.iucnredlist.org/
IWC. (1946). International Convention for the Regulation of Whaling, 1946., revised in 2018. Retrieved January 16, 2022, from https://archive.iwc.int/pages/view.php?ref=3606&k=
IWC. (2014). Report of the Joint IWC-SPAW Workshop to Address Collisions Between Marine Mammals and Ships With a Focus on the Wider Caribbean. IWC/65/CCRep01.
IWC. (2018). Total catches. Retrieved January 14, 2022, from https://iwc.int/total-catches
IWC. (2019). Report of the IWC workshop on marine debris: The way forward, 3-5 December, 2019, La Garriga, Catalonia, Spain. SC/68B/ REP/03. Retrieved on January 17, 2022, from https://iwc.int/marine-debris
IWC. (2020). Catches Taken: ASW. Retrieved January 21, 2022, from https://iwc.int/table_aboriginal.
Jefferson, T. A., Hung, S. K., & Würsig, B. (2009). Protecting small cetaceans from coastal development: Impact assessment and mitigation experience in Hong Kong. *Marine Policy*, *33*(2), 305-311.
Jensen, F. H., Perez, J. M., Johnson, M., Soto, N. A., & Madsen, P. T. (2011). Calling under pressure: short-finned pilot whales make social calls during deep foraging dives. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1721), 3017-3025.
Johnson, C., Reisinger, R., Palacios, D., Friedlaender, A., Zerbini, A., Willson, A., Lancaster, M. , Battle, J., Graham, A., Cosandey-Godin, A., Jacob T., Felix, F., Shahid, U., Houtman, N., Alberini, A., Montecinos, Y., Najera, E. and Kelez, S. (2022). Protecting Blue Corridors, Challenges and Solutions for Migratory Whales Navigating International and National Seas. WWF, Oregon State University, University of California, Santa Cruz, Publisher: WWF International, Switzerland.
Katsanevakis, S. (2008). Marine debris, a growing problem: Sources, distribution, composition, and impacts. *Marine Pollution: New Research. Nova Science Publishers, New York*, 53-100.
Konrad, C. M., Gero, S., Frasier, T., & Whitehead, H. (2018). Kinship influences sperm whale social organization within, but generally not among, social units. *Royal Society open science*, *5*(8), 180914.
Kühn, S., Rebolledo, E. L. B., & Van Franeker, J. A. (2015). Deleterious effects of litter on marine life. *Marine anthropogenic litter*, 75-116.
Lagerquist, B., Winsor, M., & Mate, B. (2012). *Testing the effectiveness of an acoustic deterrent for gray whales along the Oregon coast* (No. DOE/DE-EE0002660). Pacific Energy Ventures, LLC; Oregon State University Marine Mammal Institute.
Lambert, E., Hunter, C., Pierce, G. J., & MacLeod, C. D. (2010). Sustainable whale-watching tourism and climate change: towards a framework of resilience. Journal of Sustainable Tourism, 18(3), 409-427.
Learmonth, J. A., MacLeod, C. D., Santos, M. B., Pierce, G. J., Crick, H. Q. P., & Robinson, R. A. (2006). Potential effects of climate change on marine mammals. *Oceanography and Marine Biology, 44,* 431.
Lissner, I., & Mayer, M. (2020). Tourists' willingness to pay for Blue Flag's new ecolabel for sustainable boating: the case of whale-watching in Iceland. *Scandinavian Journal of Hospitality and Tourism*, *20*(4), 352-375.
Luksenburg, J.A. (2014). Prevalence of External Injuries in Small Cetaceans in Aruban Waters, Southern Caribbean. PLoS ONE 9(2): e88988. doi:10.1371/ journal.pone.0088988
Lusher, A. L., Hernandez-Milian, G., Berrow, S., Rogan, E., & O'Connor, I. (2018). Incidence of marine

debris in cetaceans stranded and bycaught in Ireland: Recent findings and a review of historical knowledge. *Environmental Pollution*, *232*, 467-476.

López, B. D. (2020). When personality matters: personality and social structure in wild bottlenose dolphins, Tursiops truncatus. *Animal Behaviour*, *163*, 73-84.

MacMullen, P., Hareide, N., Furevik, D., Larsson, P., Tschernij, V., Dunlin, G., ... & Sacchi, J. (2003). Study to Identify, Quantify and Ameliorate the Impacts of Static Gear Lost at Sea. *Sea Fish Industry Authority*.

Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: Threats, opportunities and solutions. *Philosophical Transactions of the Royal Society B*, *375*(1794), 20190104.

Mallard, G. (2019). Regulating whale watching: A common agency analysis. *Annals of Tourism Research*, *76*, 191-199.

Marine Protection Atlas. (2021). MPA Protection Guide. Retrieved January 16, 2022, from https://mpatlas.org/mpaguide/

Martin, A. H., Pearson, H. C., Saba, G. K., Olsen, E. M. (2021). *Integral functions of marine vertebrates in the ocean carbon cycle and climate change mitigation.* One Earth, 4(5), 680=693.

Matkin, C. O., Saulitis, E. L., Ellis, G. M., Olesiuk, P., & Rice, S. D. (2008). Ongoing population-level impacts on killer whales Orcinus orca following the 'Exxon Valdez'oil spill in Prince William Sound, Alaska. *Marine Ecology Progress Series*, *356*, 269-281.

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., ... & Soukup, M. A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, *208*, 15-28.

McLellan, W. A., Arthur, L. H., Mallette, S. D., Thornton, S. W., McAlarney, R. J., Read, A. J., & Pabst, D. A. (2015). Longline hook testing in the mouths of pelagic odontocetes. *ICES Journal of Marine Science*, *72*(5), 1706-1713.

Meesters, H. W. G., Slijkerman, D. M. E., De Graaf, M., & Debrot, A. O. (2010). Management plan for the natural resources of the EEZ of the Dutch Caribbean (No. C100/10). Imares.

MMPATF. (2020). 159 Important Marine Mammal Areas – Stepping stones to conservation – Now stretch across the Southern Hemisphere. Retrieved January 17, 2022, from https://www.marinemammalhabitat.org/download/159-important-marine-mammal-areas-stepping-stones-to-conservation-now-stretch-across-the-southern-hemisphere/

MMPATF. (2021). Guidance on the identification of Important Marine Mammal Areas (IMMAs). Retrieved January 17, 2022, from https://www.marinemammalhabitat.org/download/guidance-on-the-use-of-selection-criteria-for-the-identification-of-important-marine-mammal-areas-immas/

Morissette, L., Kaschner, K., Gerber, L. R. (2010). 'Whales eat fish'? Demystifying the myth in the Caribbean marine ecosystem. Fish and Fisheries, 11, 388-404

Moss, B. (2017). *Marine reptiles, birds and mammals and nutrient transfers among the seas and the land: an appraisal of current knowledge*. Journal of Experimental Marine Biology and Ecology, 492, 63-80.

New Bedford Whaling Museum. (n.d.). *Migration.* Retrieved October 27,2021, from https://www.whalingmuseum.org/learn/research-topics/whale-science/habitat/

NOAA. (2004). Recovery plan for the North Atlantic Right Whale *(Eubalena glacialis)*: Revision. Silver Spring, MD. National Marine Fisheries Service. Retrieved January 17, 2022 from https://repository.library.noaa.gov/view/noaa/3411

NOAA. (n.d.-a). *Species directory: Humpback whale.* Retrieved October 26, 2021, from https://www.fisheries.noaa.gov/species/humpback-whale#overview

NOAA. (n.d.-b). *Species directory: Sperm whale.* Retrieved October 26, 2021, from https://www.fisheries.noaa.gov/species/sperm-whale

NOAA. (n.d.-c). *Species directory: Short-finned pilot whale*. Retrieved October 26, 2021, from https://www.fisheries.noaa.gov/species/short-finned-pilot-whale

NOAA. (n.d.-d). *Species directory: Common bottlenose dolphin*. Retrieved October 26, 2021, from https://www.fisheries.noaa.gov/species/common-bottlenose-dolphin

Nowacek, D. P., Christiansen, F., Bejder, L., Goldbogen, J. A., & Friedlaender, A. S. (2016). Studying cetacean behaviour: new technological approaches and conservation applications. *Animal behaviour*, *120*, 235-244.

Nowacek, D. P., Johnson, M. P., & Tyack, P. L. (2004). North Atlantic right whales (Eubalaena glacialis)

ignore ships but respond to alerting stimuli. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *271*(1536), 227-231.
Onwuegbuzie, A. J., Leech, N. L., & Collins, K. M. (2012). *Qualitative analysis techniques for the review of the literature.* Qualitative Report, 17, 56.
Overheid. (2021). Yarari reservaat en aanpassingen Visserijwetgevingen CN. Retrieved February 2, 2022, from https://www.internetconsultatie.nl/yarari
Park, T., Evans, A. R., Gallagher, S. J., & Fitzgerald, E. M. (2017). Low-frequency hearing preceded the evolution of giant body size and filter feeding in baleen whales. Proceedings of the Royal Society B: Biological Sciences, 284(1848), 20162528.
Parsons, E. C. M., & Woods-Ballard, A. (2003). Acceptance of Voluntary Whalewatching Codes of Conduct in West Scotland: The Effectiveness of Governmental Versus Industry-led Guidelines. *Current Issues in Tourism*, *6*(2), 172-182.
Pershing, A. J., Christensen, L. B., Record, N. R., Sherwood, G. D., & Stetson, P. B. (2010). The impact of whaling on the ocean carbon cycle: why bigger was better. *PloS one*, *5*(8), e12444.
Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E., & Irons, D. B. (2003). Long-term ecosystem response to the Exxon Valdez oil spill. *Science*, *302*(5653), 2082-2086.
Pirotta, V., Reynolds, W., Ross, G., Jonsen, I., Grech, A., Slip, D., & Harcourt, R. (2020). A citizen science approach to long-term monitoring of humpback whales (Megaptera novaeangliae) off Sydney, Australia. *Marine Mammal Science*, *36*(2), 472-485.
Polidoro, B. A., Brooks, T., Carpenter, K. E., Edgar, G. J., Henderson, S., Sanciangco, J., & Robertson, D. R. (2012). Patterns of extinction risk and threat for marine vertebrates and habitat-forming species in the Tropical Eastern Pacific. *Marine Ecology Progress Series*, *448*, 93-104.
Protected Planet. (2021). Protected Planet Report 2020. Retrieved January 16, 2022, from https://livereport.protectedplanet.net/
Reeves, R. R., McClellan, K., & Werner, T. B. (2013). *Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011.* Endangered Species Research, 20(1), 71-97.
Reeves, R. R., & Whitehead, H. (1997). Status of the sperm whale, Physeter macrocephalus, in Canada. *Canadian field-naturalist. Ottawa ON*, *111*(2), 293-307.
Rhein, S., & Schmid, M. (2020). Consumers' awareness of plastic packaging: More than just environmental concerns. *Resources, Conservation and Recycling*, *162*, 105063.
Rinaldi, C., & Rinaldi, R. (2014). A deadly mother-calf bond in Caribbean sperm whales. International Whaling Commission 2014, SC/65b/HIMO2.
Roman, J., Estes, J. A., Morissette, L., Smith, C., Costa, D., McCarthy, J., Nation, JB., Nicol, S., Pershing, A., & Smetacek, V. (2014). *Whales as marine ecosystem engineers.* Frontiers in Ecology and the Environment, 12(7), 377-385.
Roman, J., Fisher, S., Schteinberg, R., & Galletti, B. (2017, July). *Role of Cetaceans in Ecosystem Functioning: Defining Marine Conservation Policies in the 21st Century*. In 28th International Congress for Conservation Biology. Society for Conservation Biology. Cartagena, Colombia.
Sacchi, J. (2021). Overview of mitigation measures to reduce the incidental catch of vulnerable species in fisheries.
Sanganyado, E., & Liu, W. (2020). *Cetacean Health: Global Environmental Threats*. Life Below Water, 1-14.
Sá, S., Bastos-Santos, J., Araújo, H., Pereira, A. T., Ferreira, M., Sarmento, P., Vingada., J., & Erica C. (2021). *Floating marine litter and their risks to cetaceans off Portugal.* Marine Pollution Bulletin, 170, 112603.
Schnurr, R. E., Alboiu, V., Chaudhary, M., Corbett, R. A., Quanz, M. E., Sankar, K., ... & Walker, T. R. (2018). Reducing marine pollution from single-use plastics (SUPs): A review. *Marine pollution bulletin*, *137*, 157-171.
Schoeman, R. P., Patterson-Abrolat, C., & Plön, S. (2020). A global review of vessel collisions with marine animals. *Frontiers in Marine Science*, *7*, 292.
Servidio, A. (2014). *Distribution, social structure and habitat use of short-finned pilot whale, Globicephala macrorhynchus, in the Canary Islands* (Doctoral dissertation, University of St Andrews).
Silber, G. K., Adams, J. D., & Fonnesbeck, C. J. (2014). Compliance with vessel speed restrictions to protect North Atlantic right whales. *PeerJ*, *2*, e399.
Silber, G. K., Vanderlaan, A. S., Arceredillo, A. T., Johnson, L., Taggart, C. T., Brown, M. W., ... & Sagarminaga, R. (2012). The role of the International Maritime Organization in reducing vessel threat to whales: process, options, action and effectiveness. *Marine Policy*, *36*(6), 1221-1233.

Simmonds, M. P., & Eliott, W. J. (2009). *Climate change and cetaceans: concerns and recent developments*. Journal of the Marine biological Association of the United Kingdom, 89(1), 203-210.

Singh, A., Asmath, H., Chee, C. L., & Darsan, J. (2015). Potential oil spill risk from shipping and the implications for management in the Caribbean Sea. *Marine pollution bulletin*, *93*(1-2), 217-227.

Solano-Rodríguez, B., Pye, S., Li, P. H., Ekins, P., Manzano, O., & Vogt-Schilb, A. (2021). Implications of climate targets on oil production and fiscal revenues in Latin America and the Caribbean. *Energy and Climate Change*, *2*, 100037.

Sousa, A., Alves, F., Dinis, A., Bentz, J., Cruz, M. J., & Nunes, J. P. (2019). *How vulnerable are cetaceans to climate change? Developing and testing a new index.* Ecological indicators, 98, 9-18.

Stevick, P. T., Bouveret, L. A. U. R. E. N. T., Gandilhon, N. A. D. E. G. E., Rinaldi, C. A. R. O. L. I. N. E., Rinaldi, R. E. N. A. T. O., Broms, F. R. E. D. R. I. K., ... & Wenzel, F. R. E. D. E. R. I. C. K. (2018). Migratory destinations and timing of humpback whales in the southeastern Caribbean differ from those off the Dominican Republic. *J. Cetacean Res. Manag*, *18*, 127-133.

Taylor, B. L., Baird, R., Barlow, J., Dawson, S. M., Ford, J., Mead, J. G., ... Pitman, R. L. (2011). *Globicephala macrorhynchus.* The IUCN Red List of Threatened Species 2011: e. T9249A12972356.

Téllez, R., Mignucci-Giannoni, A. A., & Caballero, S. (2014). Initial description of short-finned pilot whale (Globicephala macrorhynchus) genetic diversity from the Caribbean. *Biochemical Systematics and Ecology*, *56*, 196-201.

Teloni, V., Mark, J. P., Patrick, M. J., & Peter, M. T. (2008). Shallow food for deep divers: Dynamic foraging behavior of male sperm whales in a high latitude habitat. *Journal of Experimental Marine Biology and Ecology*, *354*(1), 119-131.

United Nations Environment Programme. (2018). Legal limits on single-use plastics and microplastics: A global review of national laws and regulations. *World Resources Institute*, 1-114.

Vail, C. (2016). An overview of increasing incidents of bottlenose dolphin harassment in the Gulf of Mexico and possible solutions. Frontiers in Marine Science, 3(110). doi: 10.3389/fmars.2016.00110 https://tinyurl.com/jwdxzdg

Vance, H., Madsen, P. T., de Soto, N. A., Wisniewska, D. M., Ladegaard, M., Hooker, S., & Johnson, M. (2021). Echolocating toothed whales use ultra-fast echo-kinetic responses to track evasive prey. *eLife*, *10*, e68825.

Vanderlaan, A. S., & Taggart, C. T. (2007). Vessel collisions with whales: the probability of lethal injury based on vessel speed. *Marine mammal science*, *23*(1), 144-156.

van Weelden, C., Towers, J. R., & Bosker, T. (2021). Impacts of climate change on cetacean distribution, habitat and migration. *Climate Change Ecology*, *1*, 100009.

Veit, R. R., & Harrison, N. M. (2017). *Positive interactions among foraging seabirds, marine mammals and fishes and implications for their conservation.* Front. Ecol. Evol. 5(121).

Warren, V. E., Constantine, R., Noad, M., Garrigue, C., & Garland, E. C. (2020). Migratory insights from singing humpback whales recorded around central New Zealand. *Royal Society open science*, *7*(11), 201084.

Weilgart, L. S. (2007). A brief review of known effects of noise on cetaceans. International Journal of Comparative Psychology, 20(2)

Werner, T., Kraus, S., Read, A., & Zollett, E. (2006). Fishing techniques to reduce the bycatch of threatened marine animals. *Marine Technology Society Journal*, *40*(3), 50-68.

Whitehead, H. (2018). *Sperm whale: Physeter macrocephalus.* In Encyclopedia of marine mammals (pp. 919-925). Academic Press.

Wiley, D. N., Mayo, C. A., Maloney, E. M., & Moore, M. J. (2016). Vessel strike mitigation lessons from direct observations involving two collisions between noncommercial vessels and North Atlantic right whales (Eubalaena glacialis). *Marine Mammal Science*, *32*(4), 1501-1509.

Wiley, D. N., Moller, J. C., PACE III, R. M., & Carlson, C. (2008). Effectiveness of voluntary conservation agreements: case study of endangered whales and commercial whale watching. *Conservation Biology*, *22*(2), 450-457.

Williams, R., Gero, S., Bejder, L., Calambokidis, J., Kraus, S. D., Lusseau, D., ... & Robbins, J. (2011). Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident. *Conservation Letters*, *4*(3), 228-233.

WWF-International. (n.d.-a). *Catching fish, not flukes and flippers: A global effort to reduce whale and dolphin bycatch.* Retrieved October 24, 2021, from https://wwf.panda.org/discover/knowledge_hub/endangered_species/cetaceans/threats/bycatch/

WWF-International. (n.d.-b). *Threats.* Retrieved October 24, 2021, from

https://wwf.panda.org/discover/knowledge_hub/endangered_species/cetaceans/threats/
Young, N. M., & Ludicello, S. (2007). *Worldwide bycatch of cetaceans: an evaluation of the most significant threats to cetaceans, the affected species and the geographic areas of high risk and the recommended actions from various independent institutions.* U.S. Department of Commerce.
Zantis, L. J., Carroll, E. L., Nelms, S. E., & Bosker, T. (2021). Marine mammals and microplastics: A systematic review and call for standardisation. Environmental Pollution, 269, 116142.

Appendices

Appendix A A list of cetaceans sighted in the Wider Caribbean Region and their IUCN status.

Table 1. List of cetaceans sighted in the Caribbean Sea and their IUCN status. And an inventory of the species with the most sightings and or large groups (Debrot et al., 2017; Debrot, De Meyer, & Dezentjé, 1998; Van Bree, 1975; Roden & Mullin, 2000; IUCN, 2021).

Species	**Scientific name**	**Species with the most sightings / large groups**	**IUCN Status**
Odontocetes (Toothed whales)			
Common bottlenose dolphin	*Tursiops truncatus*	X	LC
Long-snouted spinner dolphin	*Stenella longirostris*	X	LC
Clymene dolphin	*Stenella clymene*		LC
Rough-toothed dolphin	*Steno bredanensis*		LC
Pantropical spotted dolphin	*Stenella attenuata*		LC
Atlantic spotted dolphin	*Stenella frontalis*		LC
Striped dolphin	*Stenella coeruleoalba*		LC
Long-beaked common dolphin	*Delphinus capensis*		LC
Risso's dolphin	*Grampus griseus*		LC
Fraser dolphin	*Lagenodelphis hosei*		LC
Common dolphin	*Delphinus delphis*		LC
Tucuxi	*Sotalia fluviatilis*		EN (decreasing) (Global)
Guiana dolphin	*Sotalia guianensis*		NT
Melon-headed whale	*Peponocephala electra*		LC
Short-finned pilot whale	*Globicephala macrorhynchus*	X	LC
Pygmy sperm whale	*Kogia breviceps*		LC
False killer whale	*Pseudorca crassidens*		NT
Pygmy killer whale	*Feresa attenuata*		LC
killer whale	*Orcinus orca*		DD
Cuvier's beaked whale	*Ziphius cavirostris*		LC
Blainville's beaked whale	*Mesoplodon densirostris*		LC
Gervais' beaked whale	*Mesoplodon europaeus*		LC
Dwarf sperm whale	*Kogia simus*		LC
Sperm whale	*Physeter macrocephalus*		VU
Balaenoptera (Baleen whales			
Blue whale	*Balaenoptera musculus*		EN (increasing)
Fin whale	*Balaenoptera physalus*		VU (increasing)
Sei whale	*Balaenoptera borealis*		EN (increasing)
Common minke whale	*Balaenoptera acutorostrata*		LC
Bryde's whale	*Balaenoptera edeni*		LC
Humpback whale	*Megaptera novaeangliae*	X	LC (increasing)

* LC = Least Concern, ** EN = Endangered, *** NT = Near Threatened, **** DD = Data Deficent , ***** VU = Vulnerable

Appendix B Background information on cetacean species in this study

Humpback whale (Megaptera novaeangliae)
These large whales with a length of ca. 16 meters have a cosmopolitan distribution that involve long migration routes. In summer they reside in high-latitude feeding grounds and in winter they migrate toward the low-latitude breeding grounds in tropical waters (Debrot et al., 2017). They are often found close to the surface and shore, which makes them relatively well studied. While migrating to breeding grounds and during breeding, the male humpback whales sing a population-specific song to attract females (Warren et al., 2020). Pod sizes of humpback whales usually do not exceed 5 animals but most commonly consist of two; either a mother and her calf or a female and a male making their way to the breeding grounds (CRRU, n.d.-a). Larger pods often consist out of males, frequently displaying antagonistic behaviour towards each other in competition for females (Franklin et al., 2021). They generally feed on krill and small fish by engulfing large amounts of water (NOAA, n.d.-a). The humpback whale has a current IUCN status of ‘Least Concern’ with an increasing population in the Caribbean (IUCN, 2021).

Sperm whale (Physeter macrocephalus)
The sperm whale is the largest toothed whale, with females growing up to 11 metres and males up to 16 metres in length (NOAA, n.d.-b; Whitehead, 2018). Female sperm whales are known to stay near to breeding grounds all year round, while males often migrate into colder waters (Reeves & Whitehead, 1997). Pod sizes of sperm whales can consist of up to 50 individuals, with each pod consisting of a different composition. Pods can include females and their calves, juvenile females and males and sexually mature males who will eventually start competing for females (Konrad et al., 2018). Within pods containing females and calves, there is often communal caring and young males have also been found to be present in these types of pods (Whitehead, 2018). Due to their feeding habit of eating deep water squid, they are mostly restricted to the deeper ocean waters (Debrot et al., 2017). They can dive up to 2 km deep, but most often reach depths between 400 and 1200 metres (Debrot et al., 2017; Teloni et al., 2008; Whitehead, 2018). To hunt, sperm whales use echolocation which can locate prey at distances of up to 500 metres (Vance et al., 2021). Due to commercial whaling the sperm whale was nearly extinct (NOAA, n.d.-b) and so their current IUCN status in the Caribbean is still vulnerable (IUCN, 2021).

Short-finned pilot whale (Globicephala macrorhynchus)
The length of short-finned pilot whales varies between 3 and 7 metres, depending on the sex of the whale; males usually growing larger (International Whaling Commission, 2021). The short-finned pilot whales mainly reside in warm tropical waters in deep offshore areas and do not specifically migrate for food or breeding (Taylor et al., 2011). Pilot whales often live in pods of between 20 and 100 individuals. Pods include both female, male, and juvenile pilot whales (IWC, 2021). Females show communal caring for other juveniles in the pod, usually after they have gone through menopause. Male pilot whales do not leave their familial pods and will find a mate when coming across females from a different pod (Servidio, 2014; Téllez et al., 2014). As many other toothed whales, the diet of the short-finned pilot whales primarily consists of squid (Debrot et al., 2017). They can dive up to 1 km in search for their prey (Jensen et al., 2011). These whales are often found in mass strandings, the reasons for this are still unclear (NOAA, n.d.-c). Their IUCN status in the Caribbean is on least concern (IUCN, 2021).

Common bottlenose dolphin (*Tursiops truncatus*)

Common bottlenose dolphins can grow between 2 and 4 metres in length when reaching adulthood (NOAA, n.d.-d). Populations of bottlenose dolphin can be split into two different groups, a coastal group and an offshore group. The coastal populations can be found in coastal, shallower waters and are either long-term residents or move seasonally along the coast. As the term suggests, offshore populations are mainly found in semi-enclosed seas and have the tendency to migrate over larger distances (Debrot et al., 2017). Bottlenose dolphins have been regularly observed in the Caribbean Sea and have therefore been deemed as a resident species (Barragán-Barrera et al., 2019). Pod sizes of bottlenose dolphins tend to consist of 5 to 15 individuals but can range up to 200 individuals, usually consisting of smaller sub-groups (CRRU, n.d.-b). It is not uncommon for groups to only consist of females or males and groups to consist of different age classes. Bottlenose dolphins are extremely social and are also known to seek interaction with other species of cetacean (CRRU, n.d.-b; López, 2020). Due to their large variety in food sources, such as squid, fish, and crustaceans, the dolphins can be seen in many different environments (NOAA, n.d.-d). Their current IUCN status in de Caribbean is least concern (IUCN, n.d.).

Appendix C Interview questions and analysis

I. **Yoeri de Vries (LNV)**

1. What is the current policy in Yarari? What measures are they taking now to protect cetaceans?
2. Which islands are included in Yarari?
3. What kind of protection measures are being considered for the new policy?
4. What kind of protection/management measures should be implemented in your opinion, top 3?
5. What is the biggest threat to the four species? And does it differ per species?

II – VII. Shane Gero (Sperm whale researcher), Dolfi Debrot (WUR), Tadzio Bervoets (DCNA), Jeffrey Bernus (CCS), Chris Johnson (WWF), Jerome Couvat (CARI'MAM project)

1. Are you familiar with the movement of cetaceans species in the Caribbean?
2. Do you know of any general migration routes/movement patterns of the four chosen species?
3. Do you have access to information/documentation on ship strikes?
4. Are you aware of any fisheries interaction with cetaceans in the region? If so which and are you aware of data on this?
5. Has climate change had an effect on the migration patterns?
6. What is happening now to protects cetaceans?
7. What kind of protection/management measures should be implemented in your opinion, top 3?
8. What is the biggest threat to the four species? And does it differ per species?
9. What kind/type of data do you mostly work with? (Actual tracking data, observations, other signs of presence?)
   a. Is this data open-sourced or accessible with restrictions?
10. Who collects this field data (researchers, volunteers, public...) and who owns it?
11. Do you know of any online databases or local data collection projects of cetaceans migration and/or movement to and from or within the Caribbean? If so, is the data freely accessible?
12. What is the state of the art in the modeling of cetacean migration path or habitat suitability, within the Caribbean?
    - What are models used to compute migration path (for marine mammals)?
    - What are geographical and climate characteristics, as well as human factors to consider when building such a model?

VIII. Felicia Vachon (PhD on sperm whales)

1. Are you familiar with the movement of cetaceans species in the Caribbean?
2. Do you know of any general migration routes/movement patterns of the sperm whale?
3. Do you have access to information/documentation on ship strikes?
4. Are you aware of any fisheries interaction with cetaceans in the region? If so which and are you aware of data on this?
5. Has climate change had an effect on the migration patterns of the sperm whale?
6. What is happening now to protects cetaceans?
7. What kind of protection/management measures should be implemented in your opinion, top 3?
8. What is the biggest threat to the four species? And does it differ per species?
9. What kind/type of data did you mostly work with during your PhD? (Actual tracking data, observations, other signs of presence?)
   a. Is this data open-sourced or accessible with restrictions?
10. Who collects this field data (researchers, volunteers, public...) and who owns it?

11. What is the state of the art in the modeling of cetacean migration path or habitat suitability, within the Caribbean?
    - What are models used to compute migration path (for marine mammals)?
    - What are geographical and climate characteristics, as well as human factors to consider when building such a model?

IX. <u>Hans Verdaat (WUR)</u>

1. What kind/type of data do you mostly work with? (Actual tracking data, observations, other signs of presence?)
   a. Is this data open-sourced or accessible with restrictions?
2. Who collects this field data (researchers, volunteers, public...) and who owns it?
3. Do you know of any online databases or local data collection projects of cetaceans migration and/or movement to and from or within the Caribbean? If so, is the data freely accessible?
4. What is the state of the art in the modeling of cetacean migration path or habitat suitability, within the Caribbean?
    - What are models used to compute migration path (for marine mammals)?
    - What are geographical and climate characteristics, as well as human factors to consider when building such a model?

<u>Coding of interview transcripts</u>

Table D1 Transcript of an interview with Dolfi Debrot held on 6 December 2021.

	Important information/statements	Topic
I	Unfortunately, one of the situations we deal with in the Caribbean is that each country has its own priorities and there is no coordinated research taking place its only for small patches of the sea. So, the data is very difficult, and the methods differ.	Data availability
II	There are three kinds of movement of cetaceans in the Caribbean. You have got the big species that travel from their feeding grounds in the temperate waters to the Caribbean to birth and possibly mate. The other kind of movement that you see is smaller species that move around to make use of the seasonal abundance of food in the Caribbean. And you have species like the sperm whale that actually seem to be largely resident in the Caribbean.	Movement
III	Shipping lanes have been mapped in the Caribbean. If you look at our report, you can find them. Those are the sources that you need to consult.	Vessel data
IV	Most ship strikes that happen probably go unrecorded, simply because its big ships going really fast, and nobody even knows. You could gather this information based on post-mortem data from animals that are washed ashore. But 90% of the cadavers of marine mammals probably end up at the sea bottom, so it’s a very small fraction of cetaceans that reach shore.	Vessel strike data
V	If a cetacean washes ashore there is a very small fraction that are actually examined by someone with the knowledge necessary to actually be able to diagnose what happened to the cetacean.	Cetacean carcasses

Table D2 Transcript of an interview with Tadzio Bervoets held on 3 December 2021

	Important information/statements	Topic
I	I was involved with satellite work for Humpback whales, 1st expedition was in 2012 and after that 2014, 2015. I have data on humpback whales, but very little for the other three species.	Cetacean data
II	I have access to documentation on ship strikes. If you want to get good data, I suggest you look at the Dutch Caribbean biodiversity database. We do have instances of ship strikes but not for your specific species or region.	Vessel data
III	There is not enough data available to conclude if climate change has had an impact on the migration and movement timing of cetaceans in Yarari.	Climate data
IV	One of my main concerns about the Yarari Sanctuary is that it is still a paper park. They are now working on a management plan and supporting legal considerations for the park. Because of that there has not been adequate data selection as there should have been.	Yarari Sanctuary
V	There is not enough data on a wider scale to be able to make any or to extrapolate any results based on what has been done before.	Data availability

Table D3 Transcript of an interview with Jeffrey Bernus held on 7 December 2021

	Important information/statements	Topic
I	I think it is not only in the Yarari Sanctuary that there is poor data. For my research I did not find a lot of data.	Data availability
II	In St. Vincent there is active hunting, boats fully equipped with speers. Often 2-3 dolphins per boat per day. There are four boats a day every week going out. There is no whaling in Yarari.	Whaling activity
III	It does not make sense to apply measures on one island or two or three islands. Its not about Yarari, its not about other sanctuaries. For example, the sperm whale is protected in Dominica, but the sperm whale also moves to other places where it is not protected like St. Vincent. So, collaboration is important.	Management

Table D4 Transcript of an interview with Jerome Couvat held on 15 December 2021

	Important information/statements	Topic
I	There were some tagging companies that took place on humpback whales. The tagging lasted for several weeks, showing that some whales seemed to be heading towards the east Atlantic and some to the west Atlantic. But the tagging data stopped there, so this is just an assumption.	Tagging data

	There is not tagging plan for 2022 yet. No other cetaceans were tagged.	
II	It is an issue of concern that there is little to no documentation on ship strikes. The issue is the same everywhere which is that it is very difficult to have clear information on ship strikes. What makes it more complicated in the Caribbean and especially the lesser Antilles is that wind is blowing from the east and as I just said most ship traffic occurs on the westside, so if a ship strikes a whale on the Caribbean side, currents will make the carcass drift offshore.	Ship strikes
III	I think generally speaking noise pollution is a big problem in all oceans, so definitely an issue in the Caribbean. Talking more specifically about what we are facing here, whale watching is an issue in the Caribbean.	Threats in the Caribbean
IV	Hunting might still be a problem for the pilot whales in St. Vincent. Bottlenose dolphin have two populations. We do not know much about the offshore population but for the inshore population, coastal development is definitely an issue as it causes loss of habitat. For sperm whales ship strikes are an issue and FADs are a big threat to sperm whales.	Threats to specific species