Whales in hot water

How climate change is impacting whales and dolphins and why we need to re-whale the ocean to achieve climate goals

WHALE AND DOLPHIN CONSERVATION

WDC

Foreword

I have long known the value of whales. Of all marine life. The value of whales goes beyond the awe-inspiring excitement they bring to people - their value is intrinsically linked to the ecosystems and biodiversity they support. Yet their role as our ocean heroes is at risk because of the impact humans are having on our natural world. The time has come to see how whales and dolphins and a plethora of other species can help us find solutions to the climate crisis we have caused. We owe it to the ocean and its inhabitants to make sure that answers to the devastation that climate change is causing fundamentally includes protecting the very systems that have shielded us from its worst effects to date.

It ought not to be a novel idea that strengthening nature's systems that allow balance in the biosphere should be a priority in climate change policies. Alas, this is sadly not a theme central to the climate policy rhetoric. We must change this – we must bring to the world's attention that wildlife plays an invaluable part within this global fight.

Sadly, we are making it incredibly hard for whales and dolphins to continue their integral role in ecosystem functioning. Spinner dolphins cannot complete vital transfers of nutrients to coral atolls if chemicals continue to run through their bodies. Humpback whales cannot continue to sequester carbon in their bodies if temperature changes push their course further into the path of the human-induced threats of vessel strikes and fishing gear entanglements. Southern right whales cannot continue to stimulate ocean productivity through iron cycling if an increase in frequency and intensity of extreme weather events further reduces their numbers.

Whales and dolphins are offering a lifeline to us in the fight against climate change, and we must foster changes that return the favour by adapting our ocean activity to help them thrive. The world must see what stands to be lost if we continue to decimate their habitats, prey sources and health.

I commend Whale and Dolphin Conservation for producing this report which highlights to the world the suffering that climate change is inflicting on whales and dolphins. Often in the deepest, darkest and seemingly furthest away corners of the ocean, are the creatures who do so much to keep the world's ecosystems alive and well. Their stories could easily remain silent: their pain is not always visible; but their suffering must be heard.

I call upon those fortunate enough to be in a position of influence – be that, in the realm of Governments or industry boardrooms – to take heed of the sound advice offered in this report and to urgently foster the conditions that allow a re-whaled ocean to help us all.

Dr. Sylvia Earle,
Marine Biologist, Oceanographer & Author

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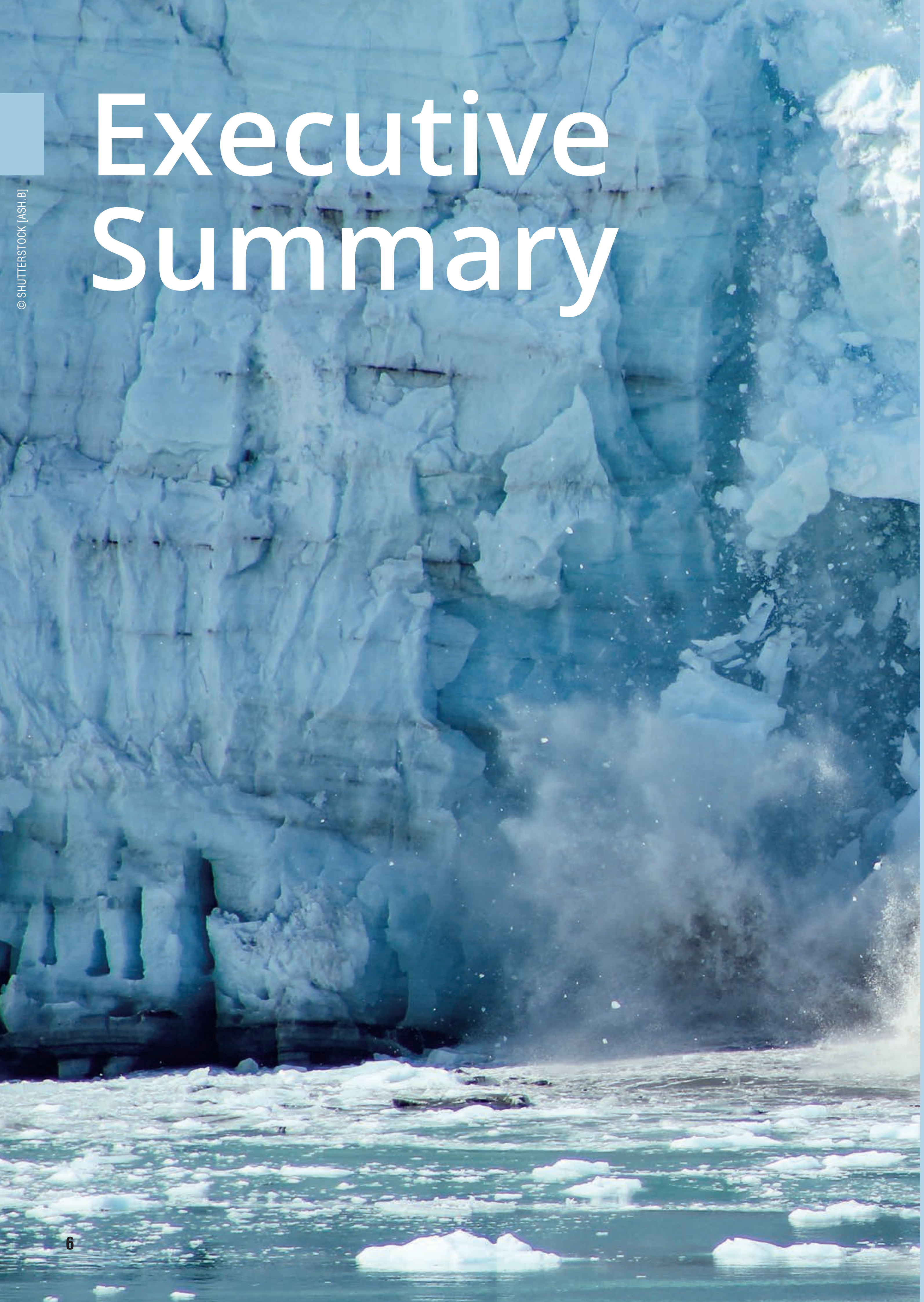
Executive Summary



Whales and dolphins are victims of the effects of climate change.

Cetaceans (whales, dolphins and porpoises) are acutely vulnerable and exposed to suffering the long and short-term consequences of climate change which are already impacting populations and threatening their very survival.

By contrast, whales and dolphins are also helping us to mitigate climate change impacts. The indispensable role that wild animals, including cetaceans, play in ecosystem functioning and the carbon-positive roles that they provide for climate change mitigation receives far less attention than trees and vegetated habitats. As such, they are insufficiently recognised in international policy discussions. Habitats and the populations of animals that live within them simply do not function in the way that they could, to help us regulate the climate.

Restoring populations of these majestic marine mammals can play a valuable role in the fight against climate change and wider biodiversity loss.

Whales and dolphins exploit a huge range of differing habitats. From the cold polar regions to the world's greatest rivers, different species of cetaceans are incredibly well adapted to their surroundings. The wellbeing of these animals is highly dependent on their habitats meeting their particular needs. Cetaceans with restricted geographical distributions and limited habitat tolerances will find it especially hard to adapt to changing environmental conditions.

Anthropogenic induced climate change is causing rapid and long-term temperature increases and extreme fluctuations, as well as catalysing impacts on the ocean with disastrous consequences, not only for whales and dolphins, but for local ecosystems and human lives too.

From the perspective of whales and dolphins, climate change is directly causing:

- Increased frequency and severity of marine heatwaves
- Increases to seawater and river temperature
- Degradation and loss of cetacean habitat
- Relocation and/or reduction of their prey
- Extreme weather events, such as flooding leading to dangerous runoff
- Harmful algal blooms
- Deoxygenation of the ocean and oceanic dead zones
- Favourable conditions for the spread of disease

The impacts of changing ocean and river temperatures, increased pollutants, toxins, algae and sediment deposits, altered hydrology, oxygen loss, and a reduction in the availability and quality of food, is leading to the following consequences for whales and dolphins:

- disrupting established ecosystems
- altered population distributions
- declining reproductive success
- increasing mass mortality events
- lower immunity and rising prevalence of injury and disease
- reduced prey abundance and quality
- rapid shifts in suitable habitat
- increased inter-species aggression

The effects of climate change on cetaceans described in this report comprise of changes that are abiotic and biotic. As climate-induced alterations affect both the living and non-living parts of the ocean ecosystem, the entirety of whales' and dolphins' environment is impacted. This is further compounded by the effect of existing anthropogenic threats on whales and dolphins and means that climate change will increasingly continue to harm individual animals and whole populations by undermining their welfare, survivability, health and reproductive success. Ultimately, this is threatening multiple species with imminent extinction.

Re-whale = the notion of helping to return the number of whales and dolphins to their pre-whaling populations.

In a world that is increasingly impacted by climate change and wider anthropogenic threats, the future of whales and dolphins is uncertain. This report demonstrates why it is in the best interest of governments, businesses and individuals to take action and support measures that protect cetaceans due to their important roles in assisting with ecosystem functioning, biodiversity support and climate mitigation and the multiple co-benefits associated with doing so.

When considering the highly pervasive impacts of climate change on marine ecosystems and species, it is essential that urgent and meaningful action is taken to ensure that whales and dolphins thrive by limiting global carbon emissions, implementing robust safeguards to protect the ocean from environmental harm, and removing other anthropogenic threats that whales and dolphins face.

Wherever you look, humans – deliberately or not – are making the ocean and rivers more and more perilous for whales and dolphins to live. This report demonstrates how climate induced issues are being compounded by other anthropogenic threats facing whales and dolphins. Cumulative pressures are a major contributor to the increasing vulnerability and wellbeing of many populations.

Whale and Dolphin Conservation (WDC) strongly believes that humans have the potential, passion and creativity to find solutions to the problems we are creating. We believe in the power of individuals, businesses and governments make a change to save our natural world. Whales and dolphins need people, in all their diversity, all over the world, to take meaningful action to protect the ocean and to remove the threats they face. We all have a part to play in protecting whales and dolphins and WDC calls on you to help us **re-whale the ocean**. Together, we can safeguard the future of these critical species, and reap the climate and biodiversity benefits they bring.

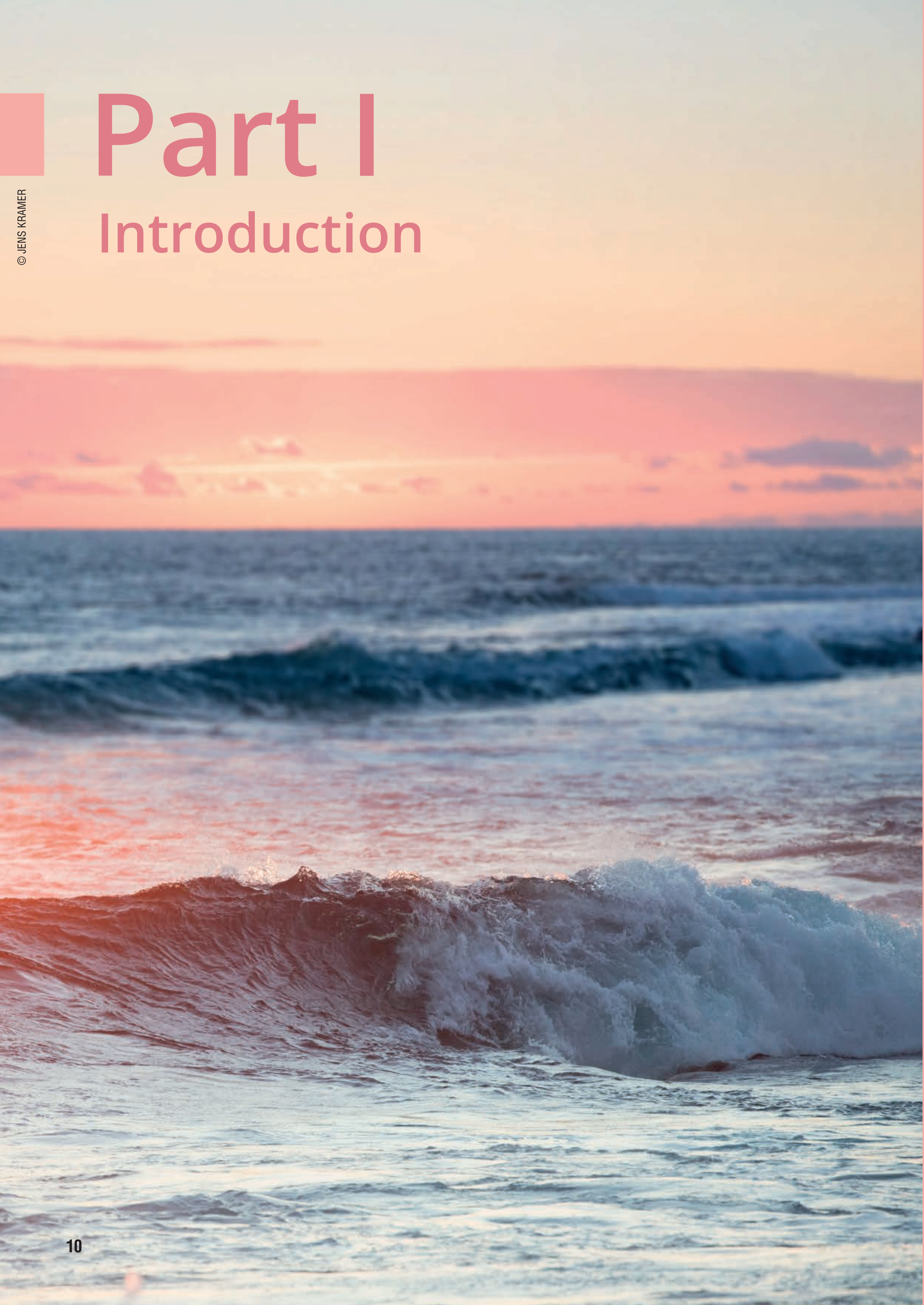
Climate change has resulted in:

- accelerated warming of the global ocean
- increasing uptake by the ocean of excess heat in the climate system
- increased frequency and intensity of marine heatwaves
- the ocean absorbing more CO_2 and increasing surface acidification
- a consequential loss in oxygen from the sea surface to a depth of 1000m

Other anthropogenic threats facing wild whales and dolphins:

- Ocean vessels
- Entanglement and bycatch
- Environmental pollution
- Whaling and hunting
- Offshore developments and underwater noise

Part I
Introduction



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WHALES AND DOLPHINS: CLIMATE CHANGE MITIGATORS AND CLIMATE CHANGE VICTIMS

Whales and dolphins are climate giants. Globally, these animals are perceived as highly significant throughout many societies and are the strong focus of a booming ecotourism industry. Yet their presence within ocean ecosystems goes far beyond human wellbeing and economic benefits – whales and dolphins play an important role in the fight against climate change and wider biodiversity loss.

Cetaceans (a term which encompasses whales, dolphins and porpoises) are already suffering the effects of climate change in a myriad of ways. In 2023, a climate-vulnerability assessment across the North Atlantic, Gulf of Mexico, and Caribbean Sea highlighted just how vulnerable and exposed marine mammals are to the consequences of climate change. In this study, no single baleen whale species scored as ‘low vulnerability’ and the majority scored as ‘highly vulnerable’. 81% of marine mammal species were found to have a high or very high possibility of experiencing a shift in distribution due to climate change[49]. These figures are not indicative of a distant threat which allows time for further environmental degradation as a result of humanity’s ‘business as usual’ approach. They demonstrate how human-induced climate-related changes are a very real and current threat to the survival of whale and dolphin populations, which will have devastating ecosystem consequences.

Despite the ocean having long acted as the primary buffer against climate change by absorbing up to 30% of anthropogenic carbon emissions and 90% of the excess heat created, discussion about its protection has only recently been factored into conversations on policy around climate change across the globe. The indispensable role that animals, including cetaceans, play in ecosystem functioning, and the carbon-positive service that they provide for climate change mitigation receives minimal attention and is not currently being recognised in international climate policy planning.

Re-whale = the notion of helping to return the number of whales and dolphins to their pre-whaling populations.

Whale and Dolphin Conservation (WDC) is advocating for Governments and industry to re-whale our planet. Introducing measures to enable these magnificent species to thrive in our ocean and rivers will recognise the valuable role that whales and dolphins play in carbon cycling and maintaining ecosystem health and reflect their position as a Global Public Good (GPG) in climate change mitigation.

The aim of this report is to present the most up-to-date ocean climate science with a synthesis of current cetacean research to build a picture of how climate change has, and is increasingly having, disastrous consequences for whales and dolphins internationally. In addition, a range of pragmatic solutions are highlighted which would prevent (or reduce) future impacts and that build cetaceans into the framework of global climate solutions.

WHAT IS A GLOBAL PUBLIC GOOD (GPG)?

A GPG is an asset of universal benefit: a common good whose use by one person or State does not deplete its availability for others. Global public goods are defined as being both non-excludable (not controlled by one particular party, where everyone has access to their benefits) and non-rivalrous (the benefit of the good by one party does not deplete its ability to be used by others). The benefits of cetacean welfare, and the ecosystem and carbon cycling benefits they deliver, are supportive of our planetary health and are of universal value to all people and countries, regardless of their proximity to the ocean.

Part II

The ocean and climate change: The story so far

The Intergovernmental Panel on Climate Change (IPCC) are the UN-appointed agency which acts as the global authority on advancing scientific knowledge around climate change. Their landmark 2019 paper, the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, provided a detailed analysis of how human actions have catalysed changes in the ocean, and offers a sobering reminder of how far-reaching these effects have been:

> *It is virtually certain that the global ocean has warmed unabated since 1970 and has taken up more than 90% of the excess heat in the climate system (high confidence). Since 1993, the rate of ocean warming has more than doubled (likely). Marine heatwaves have very likely doubled in frequency since 1982 and are increasing in intensity (very high confidence). By absorbing more CO_2, the ocean has undergone increasing surface acidification (virtually certain). A loss of oxygen has occurred from the surface to 1000 m (medium confidence)* [32]

Accelerated warming of the global ocean, through take up of excess heat in the climate system is causing increased marine heatwaves and surface acidification, and a consequential loss in oxygen from surface waters to a depth of 1000m and has a huge impact on marine life. Just as climate change is affecting the ocean in a multitude of ways, the species that rely on marine systems are affected too – many of whom act as ecosystem-drivers themselves, such as whales and dolphins. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) advised that climate change has already had a large effect on marine biodiversity through altering species distribution, population dynamics, community structure and ecosystem function, with these effects occurring at an accelerated rate in marine ecosystems[31].

Climate change effects for cetaceans are twofold through abiotic and biotic factors. Abiotic factors are non-living parts of an ecosystem that shape the environment. The most prominent abiotic factors which are shifting for whales and dolphins as a result of climate changes are: increases in seawater surface temperature (SST); extreme weather events; sea level rises; seawater freshening; and alterations in ocean currents and circulatory systems. Biotic factors are living organisms that shape the environment, such as shifts in the range of cetacean prey which is having wide reaching impacts on whales and dolphins[25]. A combination of both abiotic and biotic alterations, alongside the compound effect of existing anthropogenic threats, mean that climate change is compromising, and will increasingly continue to harm, individual animals and entire populations by undermining their welfare, survivability, health and reproductive success. Ultimately, this may threaten multiple species with imminent extinction.

The IPCC's 2023 synthesis report on climate change warns with "high confidence" that continued warming is letting humanity sleepwalk towards the risk of species extinction or irreversible loss of biodiversity in many ecosystems, while impacts on some ecosystems are approaching "irreversibility"[33]. The report also states with high confidence that it is "unequivocal" that human influence has warmed the ocean, while climate change has caused substantial damage in freshwater, polar, coastal and open ocean ecosystems, driven by increases in the magnitude of heat extremes with mass mortality events recorded across the ocean. The International Union for Conservation of Nature (IUCN) Red List 2023 statistics[37] show that overall, 1,333 species in marine regions globally are threatened by temperature extremes, with 945 species threatened by storms and flooding, and 912 species threatened by habitat shifting and alteration. These statistics do not take into account the vast number of species currently listed as data deficient.

Part III

Threats to whales and dolphins caused by climate change

There are multiple harms being caused to whales and dolphins as a consequence of climate change, which include seawater temperature change, habitat degradation and loss, reduction and relocation of prey, extreme weather events, harmful algal blooms, deoxygenation, and disease prevalence.

SEAWATER TEMPERATURE CHANGE

Sea surface temperature (SST) is one of the primary indicators of habitat suitability for cetaceans and is being drastically altered by climate change. Like all mammals, whales and dolphins are endothermic and need to maintain a constant body temperature. For cetaceans to live outside of their preferred temperature ranges requires additional energy expenditure, increases their stress responses, and potentially weakens their immune system[67]. This has implications for the survival of both individuals and populations. It is known with virtual certainty that the ocean will continue to warm throughout the 21st century[32] with estimates under the IPCC's RCP8.5 model (a 'business as usual' scenario) showing that by 2100, it is very likely that the top 2000m of the ocean will absorb up 5–7 times more heat than the observed accumulated ocean heat uptake since 1970. However, this warming is not occurring in a uniform way.

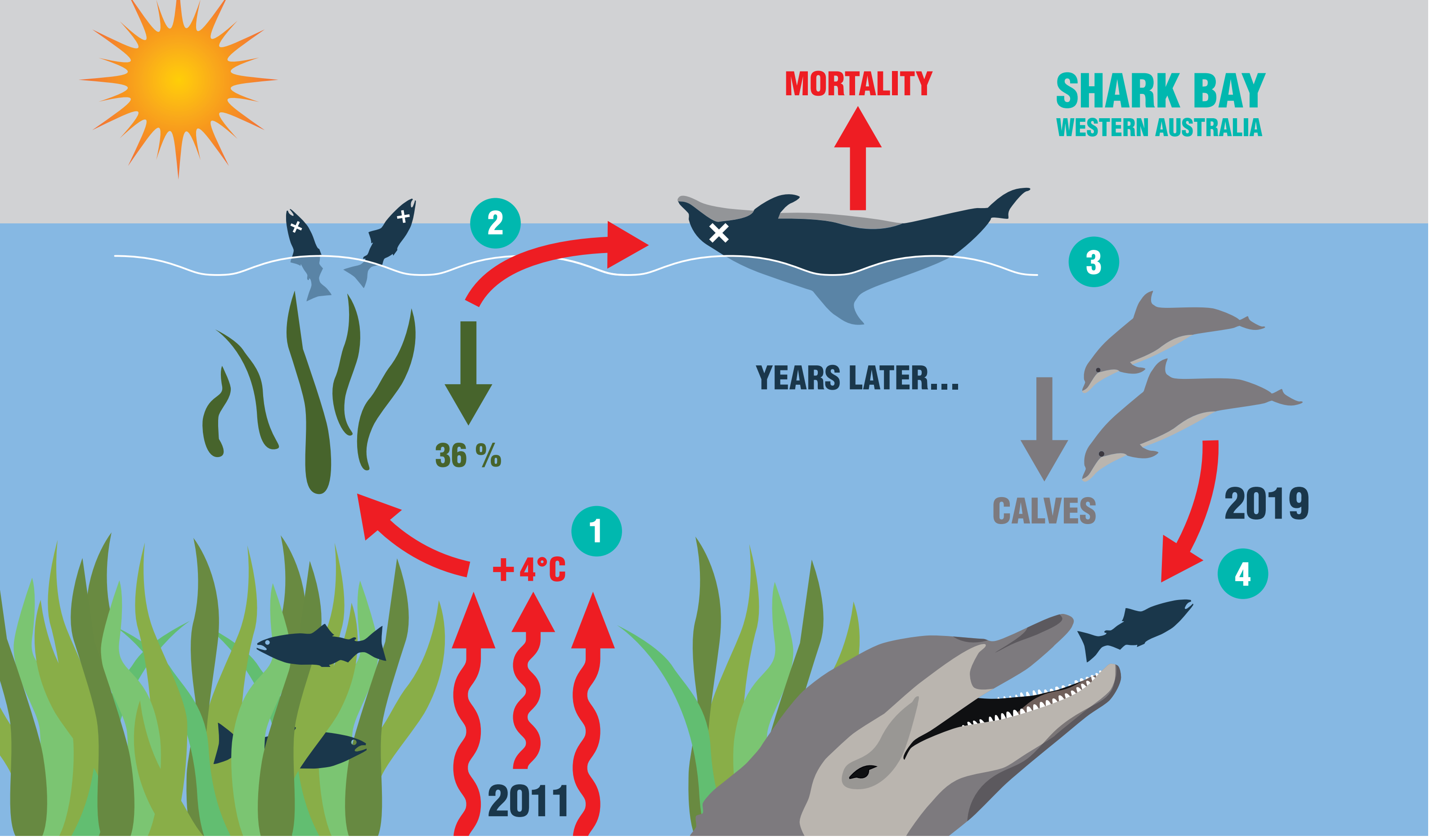
A recent species-level, trait-based approach assessment of the vulnerability of marine mammals under future warming, estimated that under several scenarios, areas hosting marine mammals which are most vulnerable to increased temperatures – the North Pacific Ocean, Greenland Sea and Barents Sea – have already undergone temperature increases 2–3 times higher than the changes to the global mean surface temperature over the past 150 years[2]. The study concluded that the North Pacific right whale and the gray whale are the two most vulnerable marine mammals, taking into account the current anthropogenic threats they are facing. Their unique combination of functional traits could have large consequences on wider marine ecosystem functioning if these two species were to become extinct. For example, the gray whale would no longer cycle large amounts of sediment in the water column which enhances nutrient availability and elevates some crustaceans from the bottom of the water to the ocean surface as food for seabirds.

Overall, changes in temperature have occurred at an accelerated rate over the last two centuries in line with anthropocentric emissions. This is leading to a contraction of suitable habitat for several vulnerable species. Even the most optimistic climate models show that there will be a further contraction of suitable habitat for species native to Arctic waters, impacting marine mammals such as narwhals which are recognised as one of the species most sensitive to climate change due to their "reliance on sea ice, restricted niche, limited range, specialised diet, and complex population structure"[9]. As the ocean warms, the southern part of the narwhal's range will not accommodate for metabolic temperature tolerances, with a movement towards higher latitudes. Climate modelling predicts temperature increases will be amplified in the northern hemisphere first. For some species which travel between temperate and polar waters, such as humpback whales, increasing temperatures may in fact lead to range expansions. This change in range can bring about its own set of difficulties, such as needing to venture out of marine protected spaces, encountering additional anthropogenic risks (such as polluted areas, industrial fishing and shipping routes), amplified competition between species for prey, and the increased spread of diseases.

MARINE HEATWAVES - IN HOT WATER

Marine Heatwaves (MHWs) are a period of time when an abnormally high temperature is recorded, relative to the average seasonal temperature of the water. The occurrence of MHWs has increased by 50% over the past decade. They now last longer, are more severe[38] and can be the catalyst for extreme weather events such as hurricanes, tropical storms and floods. This environmental variability will have wide ranging effects for whales and dolphins, as climate change induced marine heatwaves are expected to further increase in frequency and intensity.

Marine heatwaves are not isolated events that simply pass by – they can cause long-term damaging effects to the local ecosystem. There are instances across the globe where short-term temperature anomalies have had ongoing subsequent impacts. For example, in the aftermath of an unprecedented 2011 marine heatwave in Shark Bay, off Western Australia, where temperatures jumped 2–4°C above average for two



months, the increased temperature led to a loss of seagrass (approximately 36%) which is a key part of the habitat for the resident Indo-Pacific bottlenose dolphin and fish. Data collected has shown that there has been a long-term decline in reproduction rate and increased mortality in this dolphin population since the heatwave[85]. Put simply, the affected dolphins are not living as long as they ought to or producing as many calves as they were prior to the heatwave event.

Likewise, the 2014-2016 marine heatwave in the California Current resulted in similar widespread changes in ecosystem composition, including very low primary productivity, further leading to reductions in krill abundance in the area by up to 95%. Furthermore, a recent cross-analysis of acoustic data and environmental conditions for blue whales in New Zealand waters concluded that both reproductive success had decreased and foraging reduced (due to a documented decline in krill aggregations/density) during a marine heatwave[6].

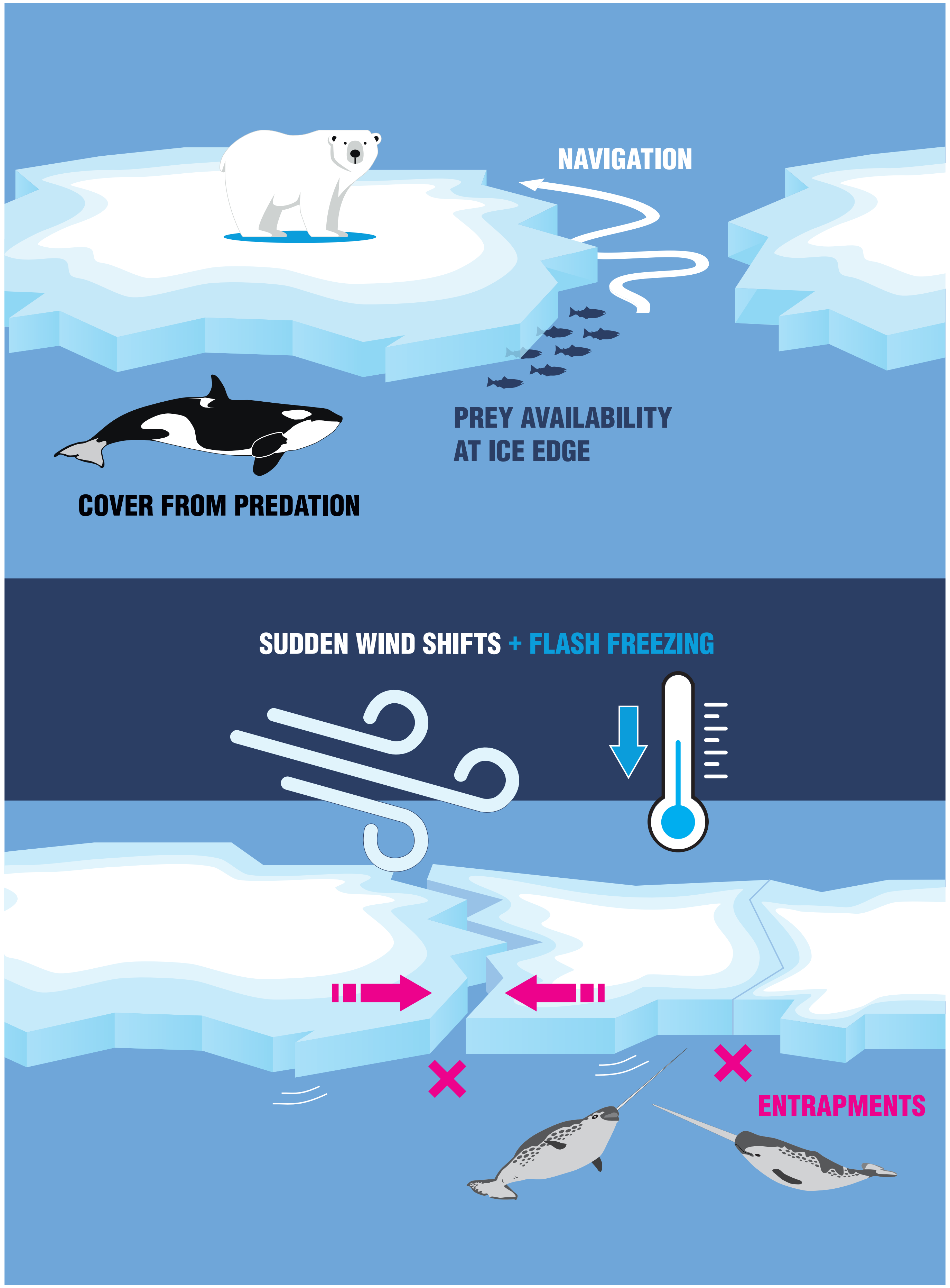
Temperature changes are not only apparent in the ocean, but in the world's rivers too. Some rivers are home to a number of species and discrete populations of dolphins and porpoises. A recent cetacean extinction-risk analysis, based on the IUCN Red List, concluded that cetaceans with a limited range, living in warmer waters and under high levels of anthropogenic impact may have a greater risk of extinction. Due to the limitations of a river range, river dolphins are geographically impeded from tracking and avoiding temperature peaks to match their thermal preferences, and their difficulties are compounded by associated factors such as temperature induced deoxygenation of the water[10]. In September 2023, a catastrophic die-off of thousands of fish and over 155 endangered river dolphins in the Amazon Basin in Brazil, coincided with soaring water temperatures. At the time of writing, no formal investigation into the cause of death had been conducted; however, it is likely that temperature tolerance thresholds were surpassed for the affected animals. These deaths occurred around Lake Tefe in Brazil, where temperatures soared to 39°C, which is 9°C above the seasonal average[30]. The issue of high temperatures is heightened by the loss of habitat and the isolating effects of hydrologic alteration, such as construction of dams. Water diversion, abstraction, and changes in the flow regime of rivers caused by hydraulic structures, constrain habitat connectivity and resource availability for freshwater populations, such as the Amazon, Ganges and Indus river dolphins[64]. The presence of man-made infrastructure throughout their distribution range restricts the movement of these valuable river residents and makes escape from temperature spikes impossible.

IUCN Red List - Cetacean Assessments* (assessment year)
Critically Endangered (CE) Endangered (E)

Atlantic humpback dolphin (2017) Sousa teuszii	CE	**Baiji** (2017) *Lipotes vexillifer* *Possibly functionally extinct	CE	**Blue whale** (Antarctic Subspecies) (2018) *Balaenoptera musculus ssp. intermedia*	CE
Indo-Pacific humpback dolphin (Taiwanese sub-population) (2017) *Sousa chinensis ssp. taiwanensis*	CE	**Māui dolphin** (2008) *Cephalorhynchus hectori ssp. maui*	CE	**North Atlantic right whale** (2020) *Eubalaena glacialis*	CE
Rice's whale (2021) Balaenoptera ricei	CE	**Vaquita** (2022) *Phocoena sinus*	CE	**Yangtze finless porpoise** (2012) *Neophocaena asiaeorientalis ssp. asiaeorientalis*	CE
Amazon river dolphin (2018) *Inia geoffrensis*	E	**Blue whale** (2018) *Balaenoptera musculus*	E	**Common bottlenose dolphin** (Black Sea sub-population) (2008) *Tursiops truncatus ssp. Ponticus*	E
Harbour porpoise (Black Sea sub-population) (2008) *Phocoena phocoena ssp. Relicta*	E	**Hector's dolphin** (2008) *Cephalorhynchus hectori*	E	**Indian Ocean humpback dolphin** (2015) *Sousa plumbea*	E
Indus river dolphin (2021) *Platanista minor*	E	**Irrawaddy dolphin** (2017) *Orcaella brevirostris*	E	**Narrow-ridged finless porpoise** (2017) *Neophocaena asiaeorientalis*	E
North Pacific right whale (2017) *Eubalaena japonica*	E	**Perrin's beaked whale** (2020) *Mesoplodon perrini*	E	**Sei whale** (2018) *Balaenoptera borealis*	E
Ganges river dolphin (2021) *Platanista gangetica*	E	**Tucuxi** (2020) *Sotalia fluviatilis*	E	*Adapted from IUCN Red List assessment data available at www.iucnredlist.org	

A recent model used different climate scenarios to analyse projected habitat suitability for blue and sperm whales across New Zealand. It forecast SST as one of the main predictor variables of habitat suitability for these animals and concluded that expected changes will lead to a poleward shift in habitat suitability for both species by 2100, increasing with the severity of the climate change. Sperm whales' habitat around New Zealand's northern offshore islands becomes increasingly unsuitable with each scenario with a five-fold increase in habitat loss in RCP8.5 ('business as usual' emissions scenario) compared to RCP2.6 (greater emissions reductions). Severe-scenario modelling demonstrated a 61% loss and decrease of suitable sperm whale habitat[63]. Similarly, SST projection modelling across areas that humpback whales prefer for their breeding grounds has shown that by 2100, 35% of breeding areas will experience SSTs above or within 1°C of current thresholds under the 'middle of the road' RCP4.5 scenario, which jumps to 67% under the RCP8.5 scenario[27.1]. This highlights the drastic impact different emissions scenarios (and the importance of cutting greenhouse gas (GHG) emissions) can and will have on cetacean wellbeing.

Changes in water temperature are already having a global effect on cetaceans and many of the consequences are not yet fully understood. Anthropogenic induced climate change is causing long-term temperature increases and extreme fluctuations, as well as catalysing marine heatwaves with disastrous consequences, not only for whales and dolphins, but for local ecosystems and human lives too.



HABITAT DEGRADATION AND LOSS

Whale and dolphin species exploit a huge range of differing habitats, even within their sub-populations. From the cold polar regions to the world's greatest rivers, the different species of cetaceans are incredibly well adapted to their surroundings. The wellbeing of these animals is highly dependent on their habitats being able to meet their particular needs. Cetaceans with restricted geographical distributions and limited habitat tolerances will find it harder to adapt to changing environmental conditions, while those with a broad home range may be able to adapt more easily[49]. It is noted that climate change is already altering cetacean habitats either through degradation or loss.

SEA ICE, SALINITY AND ACIDIFICATION

Several cetacean species inhabit waters with dense ice cover which is reducing due to climate change. Between 2001-2011, bowhead whales off Greenland were found to be travelling to higher latitudes owing to a decrease in ice cover in their usual range. Krill, a key prey of bowhead whales, rely on food sources at the ice edge, and so retreating ice is leading to a decrease in krill availability in usual locations. Meanwhile, as Arctic sea-ice cover retreats, transient (mammal-eating) orca are expanding into ice-free areas of Hudson Bay in Canada, which may put further pressure on the Arctic marine ecosystem via predation of bowhead whales[43].

Narwhals favour dense ice coverage for protection from predation, but also as a potential means to navigate and access predictable prey. The narwhal's annual migration exposes them to sea ice which is constantly expanding and receding. Narwhals rely on cracks in the ice to move and breathe, and on occasion may be susceptible to becoming trapped by ice. Climate change may be affecting the frequency and locations of entrapments by altering the timing and position of annual sea ice expansion and retreat. It is believed that more erratic weather events are causing increased entrapments in the narwhal's summer habitat, catching them off guard and resulting in deaths. Similarly, as ice is occurring later into the autumn season, narwhals delay their southward migration to their wintering grounds which can cause entrapment due to ice flash-freezing events[12].

In some cases, suitable cetacean habitats are either shrinking or becoming more isolated. In the Arctic, substantial habitat loss is projected for the three endemic species across the summer when modelling for all climate scenarios. This is particularly evident for the beluga, who are already being affected by hunting, habitat loss and fragmentation. Populations of beluga have high site fidelity (the preference of returning to a previously occupied area year on year) during the summer, meaning they are less likely to leave an established site even in the face of degradation[9].

Climate change is further contributing to the fragmentation of and threat to specific beluga populations. Recent analysis of the endangered St. Lawrence Estuary beluga has shown that climate change is now one of the main determining factors affecting population recovery, along with high levels of toxic pollutants and disturbance. This geographically and genetically isolated population was decimated by hunting, with numbers reduced by up to 90% from the turn of the 20th century until hunting was banned[87]. The population has not seen the recovery in numbers that was hoped for, and in fact, a population viability analysis conducted in 2021 concluded that "the St. Lawrence Estuary beluga population is unlikely to recover to pre-exploitation levels or meet interim recovery targets, even under (our) most optimistic scenarios, because the reproductive capacity has been reduced both by sublethal threats and by climate changes"[87].

Habitat suitability has been altered by climate variability. Unprecedented extremes in environmental conditions since the latter half of the 20th century, with below-average ice conditions and above-average water temperatures, occurred in tandem with a collapse in the biomass of prey species. Further studies have suggested that the timing of the change in population dynamics and of increased calf mortality within the St. Lawrence Estuary beluga population is indicative of environmental warming and the knock-on effects it has had within ecosystem structure. This is further demonstrated by a deterioration of the belugas body condition, which may be attributed to climate-driven changes in prey abundance in the groups' habitat[47].

The compound effect of site fidelity to an extremely polluted area (amongst other anthropogenic threats), coupled with the degradation caused by climate change through increased SST and decreasing ice coverage, means that the habitat of this isolated beluga population is simply not conducive to long-term recovery.

Ultimately, climate change has hindered revival of this overexploited population by diminishing the animals resilience to buffer other stressors and reducing the capacity or biological scope for the species to absorb and rebound from anthropogenic interference[87].

WHAT IS OCEAN ACIDIFICATION?

Over the last few hundred years, the burning of fossil fuels has increased the concentration of CO_2 in the atmosphere, up to 30% of which has then been absorbed by the ocean since the 1980s[32]. This absorption has made seawater more acidic, in turn affecting marine life which is not used to this sudden change. Certain organisms that have a hard, external calcareous skeletal structure are affected by this change in acidity, including shrimps, oysters and corals.

The consequence of acidification on cetaceans is likely indirect, but further research is needed to establish the effects of increasing acidification on cetaceans and ultimately its impact on the wider ecosystem. Experimental studies on non-cetacean species indicate that ocean acidification directly impacts the metabolism of animals[43].

Seawater salinity is a factor in the distribution of marine species as well as the ocean's ecosystem structure and functioning. The impact of seawater salinity on an ecosystem is largely driven by the physiology and tolerances of the species within it[71]. The last two decades have seen a freshening of the Arctic Ocean surface, likely driven by climate change[41]. Large volumes of river runoff mean that the surface waters of the Arctic Ocean are already less saline than the rest of the ocean, which has consequential effects on ocean circulation and climate in the Arctic and beyond. Temperature and salinity affect the density of water. Cold water and saline water are denser than fresh water from melted ice. Varying densities drive ocean currents in the deep ocean where currents are typically made of cold and saline water that have sunk from the surface. Melting ice and higher water temperatures are therefore interrupting this balance. This impact is demonstrated in the North Atlantic where surface water sinks into the deep ocean and warmer, less dense water from the Gulf Stream moves across to replace the water which has sunk, starting a chain reaction of heat and nutrient transfer across the ocean. This 'conveyor belt' process, known as the Atlantic Meridional Ocean Circulation (AMOC), may weaken if not enough water is sinking and could have far reaching effects on weather events[14], although further research is required to assess all possible outcomes. Ocean currents have many ramifications on marine life, such as assisting in navigation, moving animals and plants around the ocean, and redistributing heat and nutrients[29]. The effects of slowing currents on cetacean habitats may be far-reaching and further research is required.

REDUCTION AND RELOCATION OF PREY

It is challenging to study whales and dolphins due to the fact that they spend their entire lives in water, they can undertake vast migrations, spend extended periods of time below the surface, and their ranges often span across multiple territorial waters. Understanding the movement and distribution of cetaceans' food sources and how these may be impacted by climate change can give us a better understanding of how cetaceans are being affected. A high proportion of prey species consumed by baleen whales are invertebrates, including zooplankton such as krill. Cetacean's prey are affected by a variety of factors such as temperature, acidification, salinity, and nutrient concentrations in an area; if these conditions and changes could be better understood, the accuracy of climate modelling which incorporate impacts on cetaceans would also be more accurate[80]. Research suggests that shifts in the range of marine species are occurring four times faster than terrestrial species, with increasing evidence that the northernmost species of cetaceans around the UK and Ireland are shifting further northwards. Distribution shifts are often a functional response to ectothermic (cold-blooded) prey distributions which are sensitive to increased SSTs and decreased salinity. For example, in the English Channel, temperature changes are linked to declining body sizes of multiple copepod species, such as the longhorn copepod that have a noted 10.15% reduction[52]: these are critical prey of sand lance and herring, which are, in turn, cetacean prey.

In the Southern Ocean, warming has already begun to impact prey species such as krill, which have undergone a 30% decline in density in some areas since the 1980s (such as the Scotia Sea, a seasonal feeding ground for blue, sei, and fin whales). Recent studies show that the breeding success of the Southern right whale can be determined by krill availability[78]. Baleen whales across the Southern Hemisphere may also face increasing competition for food. Modelling has concluded that climate change will continue to drive a decrease in krill biomass with the issue being echoed throughout the ocean, illustrated by a projected 19% and 16% decline in the Pacific and Atlantic regions respectively by 2100[78]. It is hypothesised that deteriorating conditions in the availability of prey during pregnancies of female Southern right whales in the summer feeding season is likely to affect their reproductive success. In their key feeding grounds in South Georgia, an inverse relationship between krill density and alterations to SST has been identified. When cross referenced with the Southern right whales' breeding data off the Argentinian coast, a strong relationship has been demonstrated between right whale calving output and SST anomalies in South Georgia during the autumn of the previous year[45.1]. This apparent correlation between the environmental factors of SST and the subsequent drop in krill availability, and late pregnancy failure or deaths in early lactation of the Southern right whale young, has also been observed in other krill eating species in the region, such as gentoo penguins and Antarctic fur seals. A recent study of Southern right whales off South Africa found a 23% reduction in maternal body condition since the late 1980s, with the authors concluding that a drop in body condition is linked to reduced foraging success and reduced prey availability (with krill being the key food source in this area). Southern right whale mothers already lose up to 25% of their body condition during the first few months of lactation, demonstrating that a drastic drop in foraging success can also affect calf and juvenile wellbeing, and with potential knock-on effects for population growth[81].

Certain species of whale cover exceptionally long migrations. Gray whales may migrate between Mexico and Arctic waters, which is around 15,000km annually. As capital breeders, with limited energy reserves and only a 4-5 month feeding season, disruption to prey availability in the Bering and Chukchi seas can have a knock-on impact to individuals who require a large amount of energy to migrate and successfully rear offspring. A 2023 model[72] looked at the carrying capacity for eastern North Pacific gray whales and found that population dynamics are highly dependent on Arctic prey availability and access to feeding areas. Warming in the Arctic and ice retreat has made some feeding areas more accessible for longer timeframes but has coincided with a decline in overall prey biomass as well as a change in the distribution and quality of prey. While a poleward shift in North Pacific gray whales has already been observed, rising water temperatures alongside changes in benthic productivity caused by retreating sea ice is likely leading to a continued decline in prey availability. This means that the short-term positive benefit of being able to access additional feeding areas is more than counteracted by a long-term decline in the food obtained[72].

NORTH ATLANTIC RIGHT WHALES: ON THE VERGE OF EXTINCTION

North Atlantic right whales (NARW) are one of the most critically endangered of all cetaceans. They inhabit coastal waters off the East Coast of North America and, despite being protected from whaling since the 1930s, its population has not recovered significantly compared to pre-industrial whaling levels due to human induced pressures. NARW have three main anthropogenic threats that are preventing their recovery: accidental entanglement in fishing gear; vessel strikes; and climate change. In 2010, there were circa 500 individuals, which dropped to an estimated 338 by 2020[28]. NARW were classified by the IUCN as Critically Endangered in 2020. The most recent estimates indicate that the population decline may have stabilised but do not yet point towards recovery[50].

Prey

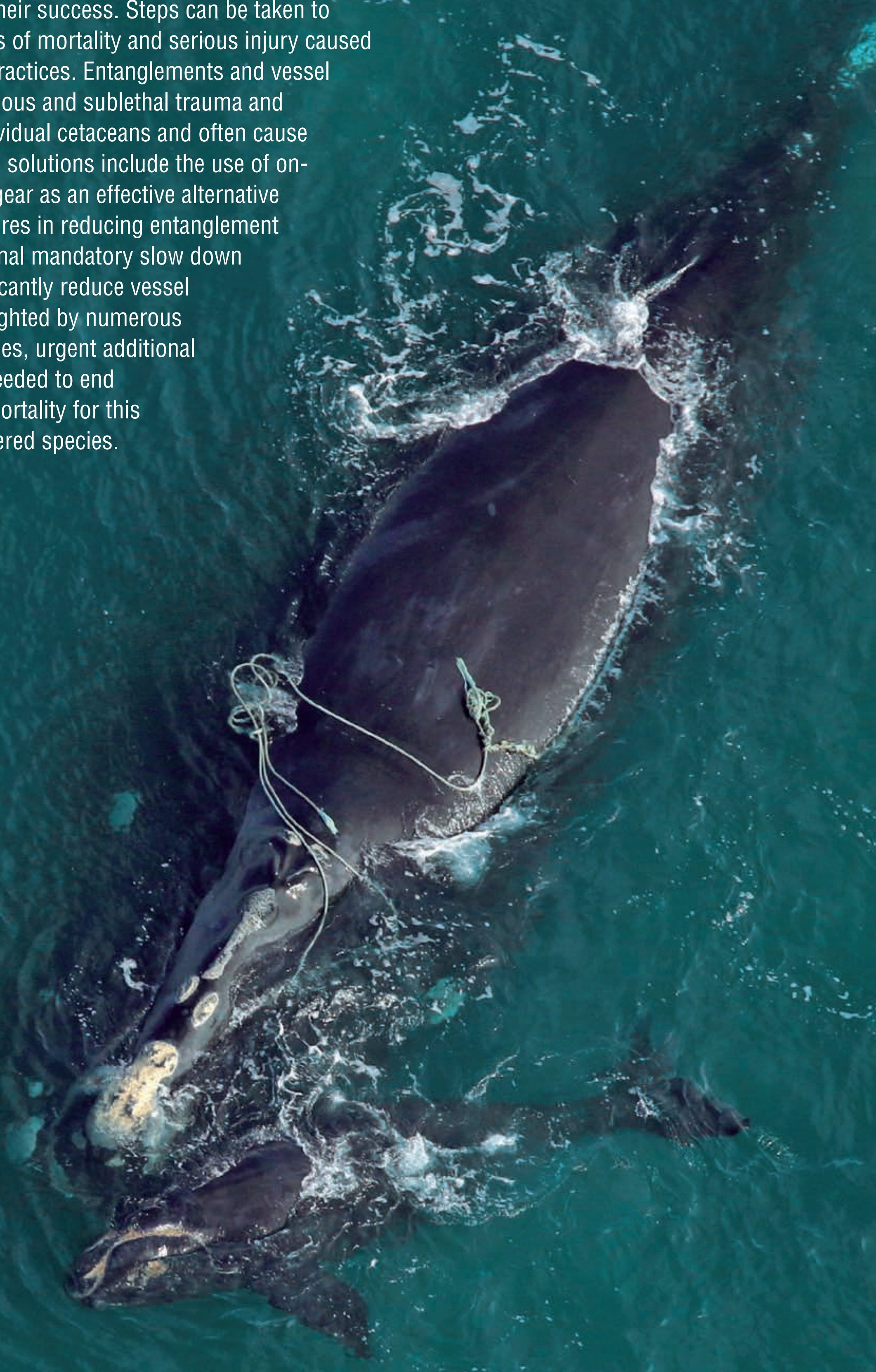
The Gulf of Maine is one of the most rapidly warming regions of the ocean. NARW are encountering changes in water temperature, circulation and the supply of their preferred prey. They have reduced their use of several of their traditional feeding habitats, such as the Great South Channel from late spring to summer and the Bay of Fundy and Roseway Basin from late summer to autumn. Recent modelling has described how this alteration is leading to a mismatch with static seasonal management measures due to changes in timing of their habitat use[62]. Calanus copepods are the primary prey for NARW, but their abundance has declined relative to increasing temperatures in the Gulf of Maine[54] and observations have noted a decline in quality of this prey. Building on previous research, recent NARW reproductive ecology modelling has provided evidence that the annual calf production of these whales is likely dependent on prey availability[56]. It is hypothesised that copepod abundance affects their foraging behaviour and subsequent likelihood of conception. During years of low prey availability, there is dispersal in search of better feeding grounds which limits mating opportunities; whereas years that have more copepod abundance results in the population converging over favourable feeding grounds and fosters prospects of improved mating.[56]

Existing threats

The combined hazards of vessel strikes, entanglements and shifting prey distributions are leaving NARW teetering on the brink of extinction. Studies of right whales from photogrammetric data across a 20-year timeframe documented a decline in body lengths and body condition of NARW coincident with entanglement, ostensibly leading to a decline in fecundity[73]. A 2019 study[70] found that chronically entangled whales have severely compromised health and concluded that entanglements are likely to negatively impact the reproductive health of right whales. The physiological and mental stress of entanglements means NARW appear to have less energy to devote to early growth, with a potential knock-on impact for reproductive success in future[73]. In 2017, an unusual mortality event (UME) was declared due to the elevated number of mortalities occurring off the USA and Canada. Based on the carcasses examined, blunt force trauma and entanglement were determined to be the proximate causes of death[25]. During this ongoing UME, official data collected demonstrated that more than 20% of the NARW population had been negatively impacted (comprising 121 animals inclusive of dead, injured, and sick individuals), although the overall total is likely to have been higher[58].

The coastal state of Massachusetts closely monitors the seasonal presence of right whales through both aerial and acoustical efforts and shares the data obtained with stakeholders[17]. In addition to observing the right whales, the state established a gear monitoring programme to ensure that abandoned fishing gear is removed from areas that are closed seasonally to protect the animals from entanglement risk[18]. Though these regulations are seasonal and such measures should be adaptive due to distributions of cetaceans are being altered by climate change, they demonstrate some pragmatic mitigation initiatives that multiple locations could adopt to support cetaceans.

Current management measures across the range of NARW are insufficient to facilitate the recovery of this species. As whale distributions shift, additional safeguards offering robust protection are required for their emerging habitats, and active monitoring and enforcement of these management measures are critical components to their success. Steps can be taken to address incidents of mortality and serious injury caused by commercial practices. Entanglements and vessel strikes inflict serious and sublethal trauma and suffering on individual cetaceans and often cause death. Innovative solutions include the use of on-demand fishing gear as an effective alternative to fisheries closures in reducing entanglement risk; while seasonal mandatory slow down zones can significantly reduce vessel strikes. As highlighted by numerous reports and studies, urgent additional intervention is needed to end anthropogenic mortality for this critically endangered species.



Poor body condition of cetaceans owing to low or suboptimal prey availability and quality affects the ability of these animals to reproduce. When energy and fat reserves are low, survival of the individual animal is prioritised and the body naturally decreases reproductive efforts, for example through reduced ovulation, delays in reaching sexual maturity, and even early-term foetal deaths[43]. Across 2004-2018, 39% of all observed humpback whale pregnancies in the Canadian Gulf of St Lawrence were unsuccessful. This is a concerning finding, especially as many known humpback breeding grounds are predicted to be increasingly unsuitable by 2100 owing to SST exceeding 28°C[43].

EXTREME WEATHER EVENTS

Climate change has already increased the intensity and frequency of extreme weather events. Both ocean and land-based climate-induced events, such as fires and flooding, impact the habitat of cetaceans.

Higher temperatures and protracted drier periods are known to be occurring due to climate change, which is leading to an increase in the frequency and severity of wildfires in different regions across the globe. Fires adjacent to river shores, which often used to take place because of human activity such as controlled land clearance for agriculture, are now increasingly occurring due to climate change. These can alter the structural stability, sediment deposits, biogeochemical cycles as well as acidity and heavy metal levels in waterways[57], the result of which often ends up in the ocean and rivers in which whales and dolphins live.

Across the globe, flooding poses a threat to resident coastal cetaceans via the transportation of terrestrially sourced pollutant run-off through freshwater discharge. An increase in precipitation caused by a changing climate can introduce toxic chemicals and contaminants potentially causing adverse effects on cetacean metabolism, such as via endocrine disruption[43]. River dolphins across South America are susceptible to the negative effects of climate change and are known as an important bioindicator whose wellbeing gives insights into the health of their ecosystem. The Orinoquía region in Colombia has experienced variations in both temperature and hydrology dynamics which have negatively impacted river dolphins. Droughts and floods affect the stability of the river pulses which river dolphins are highly dependent on due to their regulatory input on aquatic habitats[57].

The increase in climate variability and phenomena such as El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) are known to have an effect on whales and dolphins in a variety of ways, such as altering population distribution, decreasing reproductive rates and increasing mortality events[80]. An El Nino event the 1980s triggered a large northward range expansion of a bottlenose dolphin population which resulted in a new overlap in habitat with harbour porpoise, and later the first instance of aggression towards Californian harbour porpoises from a bottlenose population was recorded. From 2000, instances of stranded harbour porpoises were found to have been fatally attacked by the bottlenose dolphins[25]. This alteration in range of a species, triggered by an El Nino event, is an example of how disruptive extreme weather events can lead to conflict by mixing previously established populations. While El Ninos are a natural occurrence, anthropogenic climate change is expected to increase their frequency and impact in the future[32].

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HARMFUL ALGAL BLOOMS

A harmful algal bloom (HAB) occurs when there is a localised very rapid growth in algae in a body of water which can be toxic. While not all algal blooms are dangerous, HABs have increased in range and frequency since the 1980s, catalysed by climate change and other factors. The IPCC has highlighted that this increase is largely attributable to ocean warming, marine heatwaves, oxygen loss, eutrophication and pollution[32]. While HABs typically occur in temperate and tropical regions, a warming ocean and declining sea ice increases the factors which make it more likely for these blooms to occur. The effects of HABs can be dangerous to whales and dolphins.

> *Exposure to marine biotoxins produced by harmful algal blooms (HABs) is the leading attributable cause of large marine mammal die-offs in the U.S. Between 1991 and 2008, 50% of all die-offs declared by the National Oceanic and Atmospheric Administration's (NOAA) Office of Protected Resources (2010) as unusual mortality events (UMEs) with a known cause were a result of exposure to HAB toxins, with the majority of affected species being cetaceans.*
>
> **Fire *et.al***, 2010: 342[20]

It is known that dense HABs can cause ecosystem disruption, such as through blocking sunlight to seagrasses or damaging coral, but the full extent of the harm caused to cetaceans is not currently known; although it is possible to draw upon learnings from studies of deceased animals. For example, a recent study analysed levels of the neurotoxins domoic acid (DA) and saxitoxin (STX) in fifty-three bowhead whales, humpback whales, beluga and harbour porpoises (including several pregnant females), most of whom had been found deceased on Alaska's coast. Neurotoxins such as DA and STX are released as natural metabolites of diatoms and dinoflagellates, both of which can be part of a HAB. DA and STX toxins have been detected in waters off the West Coast of the US and are harmful to human health through consumption of seafood. DA was present in 68% of the bowhead whales, and in two of the foetuses from a beluga and a harbour porpoise; while half of all humpbacks that were analysed tested positive for STX[46]. Cetaceans are believed to ingest these toxins through their prey and their young are being exposed during pregnancy too, although the full extent of how this may affect reproduction is not yet known.

It has been suggested that certain toxins might make larger cetaceans more vulnerable to vessel strikes[46]. In 1987, a mass mortality event occurred in America's Cape Cod Bay when 14 humpback whales died after eating Atlantic mackerel containing STX. It was postulated at the time that due to the physiology of humpback whales and how STX is absorbed, it would have had an effect on the whales' heat-conserving mechanisms and ability to return to the surface to breathe, making them more vulnerable to vessel strikes[21].

There is a knowledge gap around exactly how DA affects large whales, and particularly baleen whales, who feed predominantly on prey that graze directly on toxic marine algae[20] and how bioaccumulation through the trophic web may be amplifying these risks. In 2000, brain changes were observed in samples from a stranded gray whale which was exposed to DA, while low levels of DA and STX were detected in six gray whales across a 2019-20 UME. The data available demonstrates that gray whales who are exposed to marine biotoxins[74] have a reduction in their fitness.

The issue of larger and more frequent HABs is a global concern, and an example of how climate change is exacerbating an existing threat to marine life. There is a scientific consensus that the public health, recreation, tourism, fishery, aquaculture, and ecosystem impacts from HABs have all increased over the past several decades[23]. It appears that whales are particularly susceptible to the common neurotoxins caused by HABs and may be more sensitive to smaller amounts than would be harmful to a human, despite their great size, particularly when their primary food source is exposed[20].

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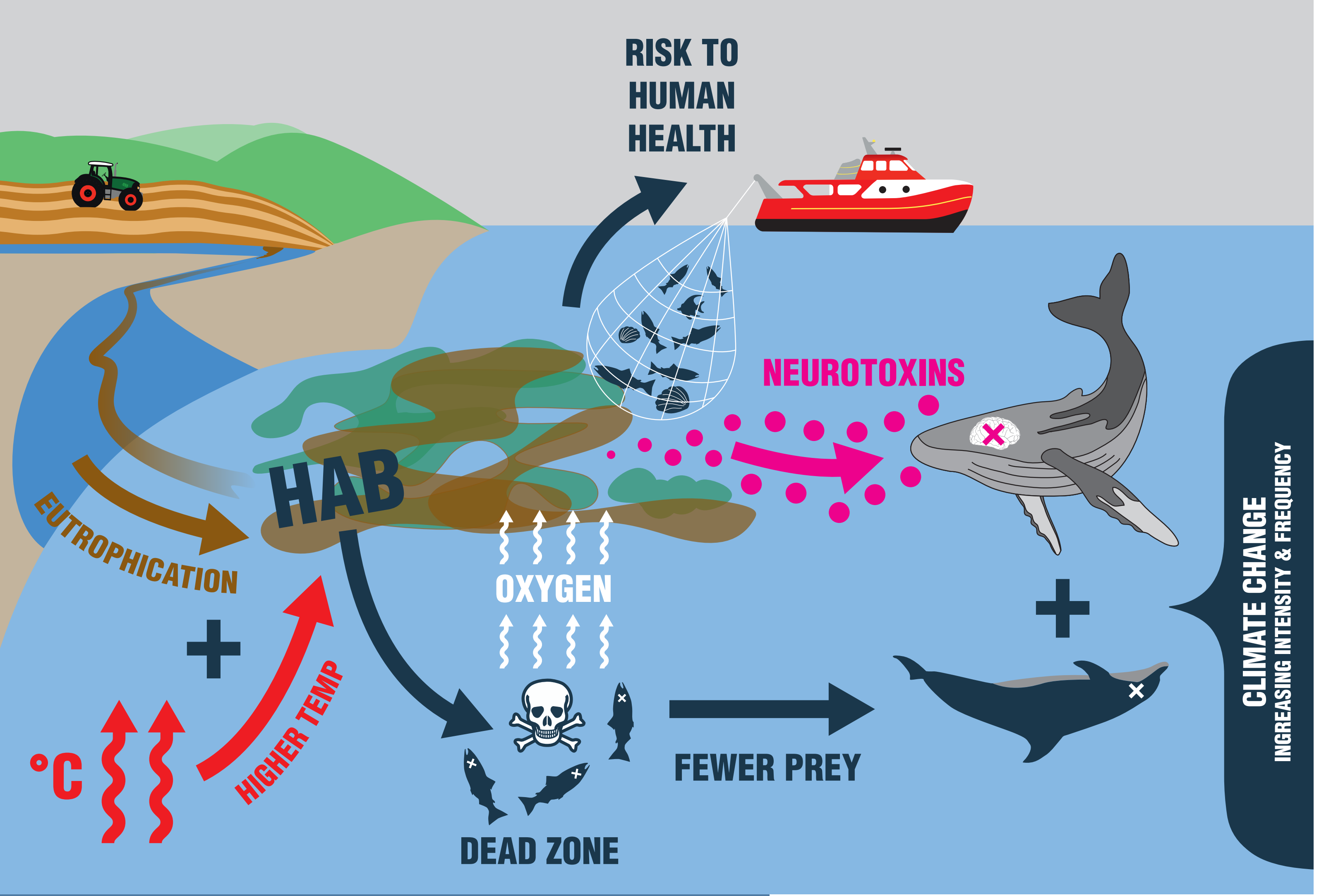

THE CHILEAN MASS MORTALITY EVENT

The largest recorded mass mortality event (MME) of baleen whales occurred in March 2015 in Southern Chile when at least 343 animals died. Little is known about the cause of many baleen whale MMEs, so the findings of the studies into this MME are insightful. It was hypothesised that sudden loud noise, which baleen whales are very sensitive to, may have been a determining factor in the deaths, but no evidence of this was found from the animals studied along hundreds of km of shoreline.

Around 69% of the whales (many of whom were endangered sei whales) had died within three months of being found in March 2015, coinciding with the strongest ever El Nino event which started in late 2014. Extremely high levels of paralytic shellfish toxins, 10 times higher than usual peaks, were reported at this time. Paralytic shellfish toxins were found in the whale carcasses and were abundant in their local prey, meaning that an algal bloom was the most probable cause of this tragic event. With the deaths being connected to El Nino-triggered events in the Eastern Pacific, researchers warned that this "could indicate that marine mammals are among the first oceanic megafauna victims of global warming"[26].

DEOXYGENATION

Warm water holds less oxygen than cold water because the higher the ocean temperature, the less soluble oxygen is. Warming waters therefore suffer from deoxygenation, and this may decrease habitat quality and food abundance for cetaceans[10]. Oxygen is crucial to life under the sea. The global ocean oxygen inventory has decreased by ~2% over the period 1960 to 2010, while ocean model simulations project a further decline of up to 7% by the year 2100[44]. Deoxygenation is occurring both on a global long-term scale and within localised events. Coastal hypoxia (low or depleted oxygen levels) is increasing in critical marine mammal habitat. The IUCN summarises ocean deoxygenation broadly as the result of two primary causes:

> *Eutrophication (as a result of nutrient run-off from land and deposition of nitrogen from the burning of fossil fuels), and the heating of ocean waters due to climate change, primarily causing a change in ventilation with the overlying atmosphere and a reduced ability to hold soluble oxygen.*
> **Ocean deoxygenation: Everyone's problem**[44]

When algal blooms die or are eaten by zooplankton, the bacteria that decompose this organic matter take in oxygen from the surrounding water, which can lead to hypoxic water conditions. This can create what is often referred to as a 'dead zone' – an area of water in a lake, river or ocean that cannot support life. This has knock-on effects on human livelihoods and ecosystem functioning as well as a negative impact on foraging efforts for cetaceans who may have to travel further afield for food. Low oxygen levels can reduce the ability of some prey species to fight pathogens and parasites, while the subsequent energy deficiency increases mortality from diseases, leading to lower prey availability for cetaceans.

The Baltic Sea harbour porpoise sub-population (the Baltic's only resident cetacean) are critically endangered and are a frequent victim of bycatch, as well as being affected by changing prey distribution, noise and environmental contaminants. It is estimated that only around 27% of female Baltic Sea harbour porpoise live long enough to support a calf, while fisheries bycatch of the Baltic Proper subpopulation is unsustainably high[11]. With only a few hundred animals left[5], these human-caused threats to the population's survival are being additionally compounded by the impacts of climate change. The Baltic Sea contains the largest anthropogenic hypoxic area in the world. Nutrient influx and inflows from the North Sea which ventilate the oxygen-poor bottom layers are now occurring only once per decade, compared to 5-7 times per decade during the 20th century, and have led to hypoxic areas have expanding from 5,000 to 60,000km^2 over the past century[59]. Ecosystem productivity is changing in the area. The Eastern Baltic cod, a prey preference of this harbour porpoise population, have decreased in average maximum size, from around 80cm in the 1980s to around 40cm today, while deoxygenation is predicted to continue the reduced size and biomass of other fish which may limit prey availability for cetaceans[59].

Deoxygenation is a far-reaching problem that has multiple impacts: altering or compressing habitats for many species; affecting migrations both across the ocean and within the water column; altering biogeochemical cycles and food webs; decreasing biomass via loss of prey and lower reproduction; and causing coastal dead zones. Such consequences have devastating effects on ocean biodiversity and will impact coastal communities who rely on fishing for their livelihoods. Since the 1960s, the area of low oxygen water in the open ocean has increased by 4.5 million km^2 and over 500 hypoxic sites have been identified in coastal waters[68]. A recent climate model simulation estimated that under the high emissions global warming scenario, more than 72% of the global ocean is projected to experience an emergence of deoxygenation before 2080[24], which will have vast impacts on biodiversity. Radical reductions in GHG emissions, as well as action to limit nutrient runoff, are urgently required to reduce the rate of oxygen decline in the ocean and prevent system collapse.

DISEASE PREVALENCE

Rising temperatures, changes to prey availability, and the bioaccumulation of pollutants are potentially increasing cetaceans' susceptibility to disease by weakening their immune systems. Furthermore, the combination of the physiological stress caused to animals by living at the limits of their thermal tolerance, coupled with changes in migratory routes or habitats due to the factors listed previously, create the perfect conditions for the spread of disease.

The occurrence of MMEs of marine mammals related to infectious disease have increased significantly over the last 30 years. In a global analysis of infectious-disease related MMEs by pathogen type of marine mammals (including cetaceans) between the years 1955-2018, it was concluded that 61% of outbreaks occurred during positive SST anomalies. For cetaceans, these occur at higher rates during summer and autumn. It is speculated that the amplifying effects of climate change on natural weather patterns and extreme weather events at these times of the year may be affecting hosts' susceptibility and pathogen exposure. Factors such as increased intensity and frequency of rainfall triggering flooding and erosion may be aiding in microbial and chemical dissemination into marine environments[67].

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Part IV

Re-whale the ocean: Recognising whales as a solution to the biodiversity and climate crises

Whales, dolphins and all animals play a contributing role in the carbon cycle by enhancing natural carbon capture and storage. In a wider sense, the conservation and restoration of wild animal populations (i.e., trophic rewilding) is key to attaining our climate and biodiversity goals[67.1]. For cetaceans, the nutrient transfer and carbon capture (both through their own bodies and the phytoplankton productivity enhancement) demonstrates how policies that support and promote their conservation can act as animal-driven ocean carbon storage enhancement programmes and thus help to support climate mitigation goals.

Recognising and supporting wild animals' functional roles within ecosystems is paramount. Yet, many of the world's climate change mitigation goals are very heavily centred on at-source emissions reductions as the primary solution for climate change. While this is undoubtedly a top priority, the role of Nature based Solutions (NbS) cannot be understated. All ecosystems have a role in climate regulation, but the ocean has acted as the primary buffer against human-induced climate changes. Supporting ocean systems to thrive and ensuring the wellbeing of keystone species within them is an overlooked and crucial tool for both climate mitigation and adaptation targets that also offer a range of co-benefits for people, nature and the planet. There is increased international attention on the need to simultaneously tackle the climate and biodiversity crises. UNFCCC COP25 was the first 'Blue COP' and COPs 26 and 28 had a very strong focus on nature, which is mirrored within the ambitious targets of the Kunming-Montreal Global Biodiversity Framework. However, it is deeply concerning that the world is not on track to meet any biodiversity or climate targets on time. Rewilding projects are taking place across a range of terrestrial landscapes, in an attempt to return balance to and strengthen compromised ecosystems. There are also some coastal rewilding initiatives underway. This concept must be extended more widely to urgently rewild all marine environments, including far offshore, where so many species have been decimated by human interference.

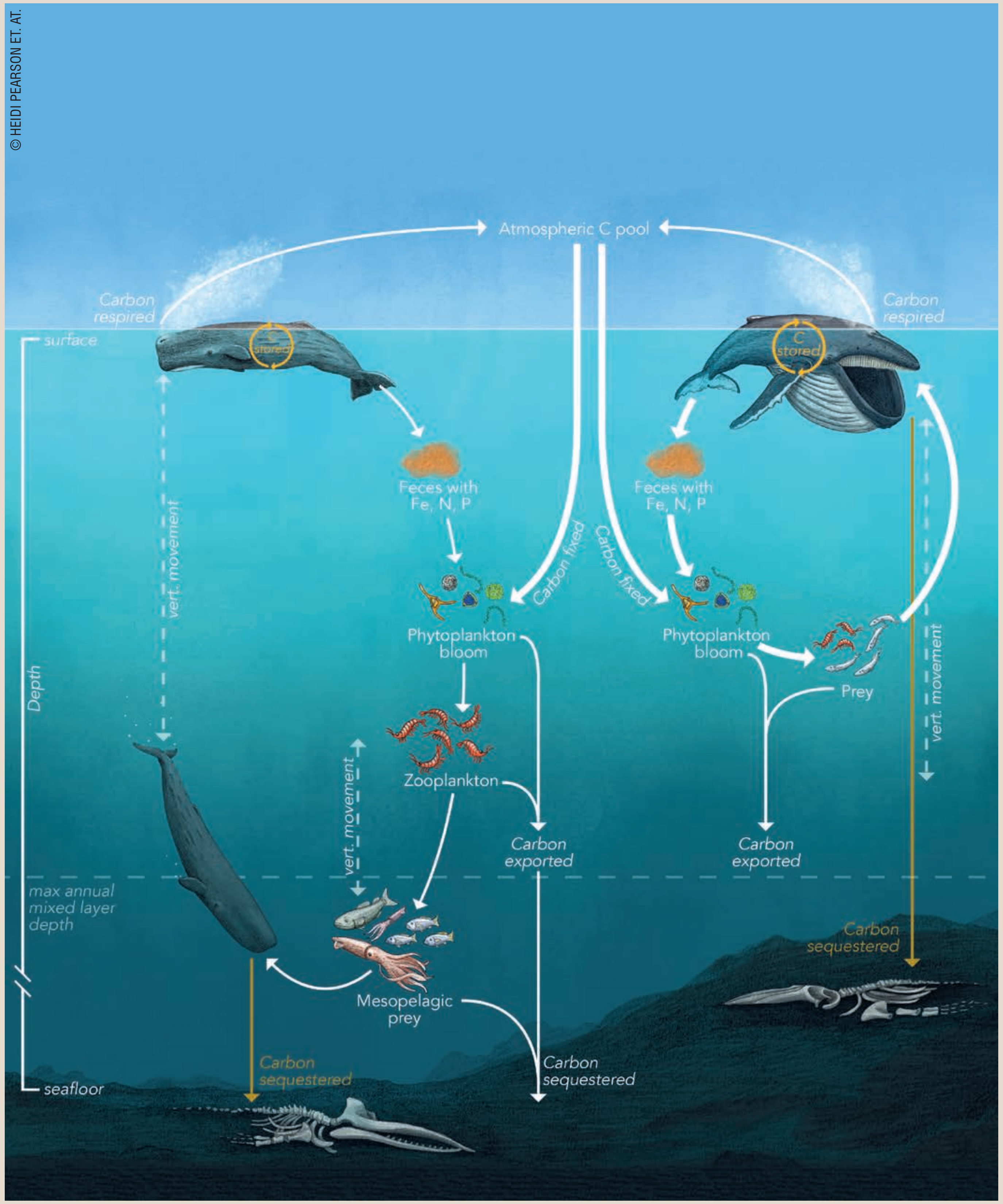
Cetaceans are 'ecosystem engineers' and, through various processes, help to facilitate carbon capture from the atmosphere. Ecosystem engineers are those animals who "also contribute to ecosystem adaptation to climate change by promoting complexity of trophic webs, increasing habitat heterogeneity, enhancing plant dispersal, increasing resistance to abrupt ecosystem change and through microclimate modification"[51]. Capturing excess atmospheric CO_2 and storing it within terrestrial and aquatic biomass and ecosystems is a natural solution to the climate crisis. An immediate focus on escalating efforts to support nature-based negative emissions solutions is required alongside delivering reductions in output-emissions. Facilitating both of these solutions will reduce global mean temperature rise and prevent further catastrophic climate change effects.

NbS have gained traction in the international policy sphere aimed at strengthening the fight against climate change. However, NbS are not being promoted or harnessed to their full potential because consideration of wild animals and the non-coastal ocean have so far been largely neglected in global policy. The vast majority of current NbS discussion is focused on the carbon storage potential of vegetation, and in the ocean conservation world, the topic of 'Blue Carbon' focuses largely on coastal vegetation and habitats, such as saltmarshes, seagrasses and mangroves, which are becoming established in IPCC GHG inventories and within Nationally Determined Contributions (NDCs). There are hugely significant stores of carbon in deep-sea sediments which are under threat of being released into the atmosphere because of disturbance to the sea bed from deep-sea fishing and mining. The potential contribution of megafauna such as cetaceans and other mobile species to reducing climate change and promoting biodiversity has received little attention, despite being recognised several years ago by international fora:

> *[IWC] encourages contracting Governments to integrate the value of cetaceans' ecological roles into local, regional and global organisations on biodiversity and environment, including climate change and conservation policies;*
> **International Whaling Commission (IWC)** 2018: Resolution 2018-2

> *Cetaceans, particularly highly migratory great whales, make significant ecological contributions to the functioning of marine ecosystems that are beneficial to the global environment, including nutrient distribution and carbon sequestration from the atmosphere*
> **Convention on Migratory Species (CMS)** 2017: Resolution 12.17

Scientists are in the process of ascertaining stronger evidence of the degree to which cetaceans contribute to carbon fixation, storage and sequestration, but the absence of precise data must not prevent immediate conservation measures from being adopted by governments and industries. Existing knowledge reveals the complex and essential roles that whales and dolphins play in supporting the ocean's biodiversity and carbon sequestration through three processes known as the whale pump, whale fall and whale conveyor belt.



WHALE PUMP

Marine phytoplankton are described as the Earth's life support system, but 50% of phytoplankton biomass have been lost since the 1950s with the decline continuing at 1% year on year[19]. After feeding at depth, whales come to the surface to breathe. At the same time, nutrient release through whale faecal plumes provide vital nutrients which are used by phytoplankton. Phytoplankton absorb around 30% of the human induced CO_2 from the atmosphere via photosynthesis, while also producing half of the world's oxygen (though most of this is retained in the ocean and used by marine life). Whale faeces is some of the most iron-rich material in the ocean and is crucial to primary productivity. Whales help to recycle iron in surface waters as they have an iron-rich diet, and excess iron which is not required is excreted within buoyant, fluid-like faeces, which acts as a natural fertiliser. This form of 'biological recycling' helps to increase the amount of bioavailable iron in large areas of the Southern Ocean surface waters, where it is naturally low[65]. By consuming prey at depth and defecating iron-rich faeces near the sea surface, some whales also stimulate new primary production and carbon export to the deep ocean. A study examining one localised species, estimated that Southern Ocean sperm whales defecate 50 tonnes of iron each year[45].

WHALE FALL

When whales die, their carcasses often sink to the ocean floor. A carcass stores a vast amount of carbon while also providing food for numerous, specialised species. The sheer magnitude of a whale's body means that these animals efficiently transfer carbon to the deep sea. It is estimated that prior to industrial whaling taking place, $3.6x10^{-4}$Gt of carbon was sequestered by whale falls from the large number of baleen whales that were in the ocean. Due to the subsequent drastic reduction in the baleen whale population, this is said to have reduced to $6.2x10^{-5}$Gt of carbon today. The significant removal of whales from the ocean and, specifically, the loss of larger species and larger individuals, has drastically altered the flux of whale carbon to the deep sea[61].

WHALE CONVEYOR BELT

As well as the whale pump, which is a vertical transfer of nutrients, whales also transport nutrients horizontally across latitudes, promoting additional primary production. Through their migrations, cetaceans assist in the relocation of nutrients across the ocean from nutrient rich (higher latitude) regions to nutrient poor (lower latitude) regions. In doing so, whales and dolphins help support the productivity of their breeding and calving areas, by bringing nutrients along with them through their travels. Smaller species have been shown to increase the productivity of coastal ecosystems by relocating nutrients from offshore to onshore – by traveling from where they feed during the night to where they rest in the day. For example, spinner dolphins provide crucial nutrient subsidies to the coral atolls they frequent. It was recently estimated that one dolphin pod deposits approximately circa 288kg a year of nitrogen inside an atoll lagoon, likely enhancing coral reef productivity[48].

Research is ongoing to discover and quantify the specific carbon and nutrient cycling roles of different whale species. Yet, it is already known that efforts to **re-whale the ocean** – taking action to restore the whale and dolphin populations to their abundant pre-whaling levels – would act as a natural enhancement of an already functioning CDR (carbon dioxide removal) process and offers a low risk, high efficiency, more permanent solution than costly geoengineering projects. Whale recovery has the potential for long-term self-sustained enhancement of the ocean carbon sink by increasing the standing stock of stored carbon and carbon sequestered in the deep sea via direct pathways (whale falls) and enhancing carbon pump via indirect pathways (whale pump and conveyor belt processes)[61].

Knowledge that restoration of whale and dolphin populations will increase the ocean's capacity to draw down carbon should play a role in increasing ambition towards their conservation. It is known that commercial whaling reduced cetacean biomass by 81%[61], resulting in the removal of an estimated 17M tons of stored carbon; and the removal of this biomass altered oceanic biological processes linked to further carbon cycling dynamics. Blue whales were severely impacted by whaling and the Southern Ocean population is estimated to currently fix $5.1x10^{-7}$Gt of carbon per year via the whale pump. Pre-whaling, this figure would have been $5.1x10Gt^{-4}$, highlighting the vast and underutilised gap in the significant climate restoration potential of reestablishing cetacean abundance[61].

PROACTIVE CONSERVATION MEASURES TO HELP RE-WHALE THE OCEAN

The framework for national and international conservation measures that will help to **re-whale the ocean** are already in place but can be expanded and enhanced to proactively restore cetacean abundance.

Climate Ambition

Anthropogenic climate change has been brought about via rampant GHG emissions. Ambitious emissions reductions targets and investments in lower-carbon manufacturing and transportation and renewable energy, are now insufficient to tackle the climate crisis alone. Transitioning to green energy and environmentally friendly industries must be undertaken in tandem with increased action to protect and restore natural biodiversity to prevent ecosystem collapse.

Climate modelling foresees a world of depleted fish populations, arid and unproductive land, polluted air and entire cities rendered uninhabitable due to heat, fires and floods. Biodiversity – both marine and terrestrial – is also being affected by these changes but must now be viewed by governments and industry as part of the solution to achieving global climate ambition.

Whales and dolphins are a Global Public Good (GPG), meaning they are an asset of universal benefit: a common good whose indirect use of services by one person or State does not deplete its availability for others. The benefits that cetaceans bring to the ecosystem, biodiversity and carbon cycling are supportive of the planet's health and are of universal value to all people and countries, regardless of their proximity to the ocean. If whale and dolphin populations are supported to return to pre-depleted levels, they will provide a self-regulating and natural form of defence against climate change that benefits everyone, regardless of the country they live in. The expansion of Blue Carbon initiatives to incorporate the restoration of ocean fauna and wider biodiversity centred policies as NbS for climate change mitigation must be implemented urgently.

Adaptive Conservation Policy

Both reactive and pre-emptive measures are needed to help cetacean populations thrive in their habitats. In some cases, existing conservation measures may need to be reevaluated and reformulated in line with the most up-to-date climate science and cetacean data.

A recent study set out to determine if currently designed marine protected areas (MPAs) around the world are spatially appropriate to offer the protection that is necessary for 'highly mobile marine megafauna'[15]. It concluded that MPAs can prove invaluable if they effectively preserve areas where cetaceans congregate for important life stages, such as breeding or feeding grounds. The placement of MPAs is critical for their effectiveness in supporting wide-ranging species. For example, US National Marine Sanctuaries encompassed nearly 30% of the core area of wide-ranging humpback whales, but only 7.1% of 'core areas' (migratory paths and foraging) of blue whales tracked in the study overlapped with global MPAs[15]. It is also noted in this report that the impacts of climate change on the ocean and rivers are forcing cetaceans to venture into new areas and habitats. Therefore, area-based management tools such as MPAs must be designed or redesigned to be responsive to this. Alongside static MPAs (those with defined geographic borders) there is a pressing need for the creation of mobile MPAs (sometimes called mMPAs) which are dynamic and proactive management tools that are able to deliver protection measures that will better adapt to the changing natural world.

Dynamic area-based management tools such as mobile MPAs could be outlined in a number of ways and derived from environmental characteristics, such as sea surface temperature bands, by determining the presence of specific species through visual or acoustic detection, or by predicting habitats or species occupancy through modelling or forecasting[53]. This form of management could result in less stringent permanent limitations on human activities if those restrictions are based on up-to-date information on species area use and are balanced out with the potential threats cetaceans face in an area. Due to ongoing changes in cetacean distribution, binding and enforced legislation must offer dynamic and robust protection to whales and dolphins which does not have the same lengthy implementation process as static MPAs[80].

IMPORTANT MARINE MAMMAL AREAS (IMMAS)

What is an IMMA?

> *"A discrete portion of habitat, important to marine mammal species (including cetaceans), that has the potential to be delineated and managed for conservation' where an 'important' area is 'any environmental condition, biological property, or value of a place, which supports marine mammals, and maintains or improves their conservation status'*
> **IUCN-MMPATF**, 2023.

The Marine Mammal Protected Areas Task Force (MMPATF) was established in 2013 as a joint venture between the IUCN and the International Committee on Marine Mammal Protected Areas (ICMMPA). This task force facilitates an international community of scientists who have assessed extensive research to establish areas of significance for cetaceans by identifying habitats that support critical life functions. Areas are assessed for their importance for vulnerable species, abundance of populations, key life cycle activities (such as feeding and breeding and migratory routes), and any special attributes such as particular species diversity. As of September 2023, 242 IMMAs have been identified across the globe.

The information and research outputs of the IMMA programme should inform industry practices and be integrated into national and international spatial planning. The findings of the task force can be used to inform environmental impact assessments (EIAs) to determine if the location of shipping, fishing and other industry practices are likely to risk cetacean wellbeing. States can design and implement monitoring programmes for IMMAs within their waters or consider using the findings to designate Marine Protected Areas (MPAs) to further ensure the resilience of important marine spaces in the face of climate change.

Expanded Research and Monitoring
There is a geographically uneven distribution of funding, research and knowledge surrounding the impact of climate change and other anthropogenic threats on cetaceans. It is also essential to fill key research gaps in ecosystem functioning knowledge to be able to quantify related natural capital value. Doing so will potentially unlock new revenue streams that can be used to reduce threats and potentially redirect harmful subsidies towards activities that restore natural capital.

Currently, studies are primarily conducted in the northern hemisphere (particularly North America). In addition, cetacean species are unequally represented in the climate change literature with research on beaked whales and river dolphins falling short compared to larger whale species[80]. This presents a significant research gap that needs to be addressed if appropriate reactive and responsive measures are to be put in place to improve their wellbeing and conserve the numbers.

Investment into climate vulnerability assessments, prey availability monitoring, data tracking (including cetacean movements in relation to factors such as temperature and deoxygenation), stranding analysis and new technologies can all help to inform the most appropriate and pragmatic actions which can be taken to help cetaceans adapt to the pressures caused by climate change and to reduce further from anthropogenic harm. Innovation can come in all shapes and sizes and is not just the responsibility of coastal States. Cross-industry collaboration is key to effective climate and conservation solutions.

Intergovernmental Engagement
Fora that are responsible for the trajectory of cetacean wellbeing need more State and industry representatives to promote cetacean welfare. The International Whaling Commission (IWC) membership is open to any country in the world, landlocked or coastal, yet only 88 countries are currently signatories to the convention, leaving 107 potential member States without a voice. As migratory animals, whales and dolphins need cross-border cooperation to ensure effective conservation measures are enacted. The Convention on Migratory Species (CMS) welcomes further State Parties to the convention which is the global platform for the conservation and sustainable use of migratory animals and their habitats. A legally binding United Nations 'Plastics Treaty' is in under negotiation, with 175 states working to formulate an agreement during 2024 to tackle plastic pollution from source. The United Nations' UNWTO Framework Convention on Tourism Ethics could be a powerful tool for ensuring responsible whale watching; this convention has been adopted but is awaiting further State signatories in order to come into effect. Multiple other political forums exist where policies and guidelines can be created to protect cetaceans and active international governmental engagement is needed.

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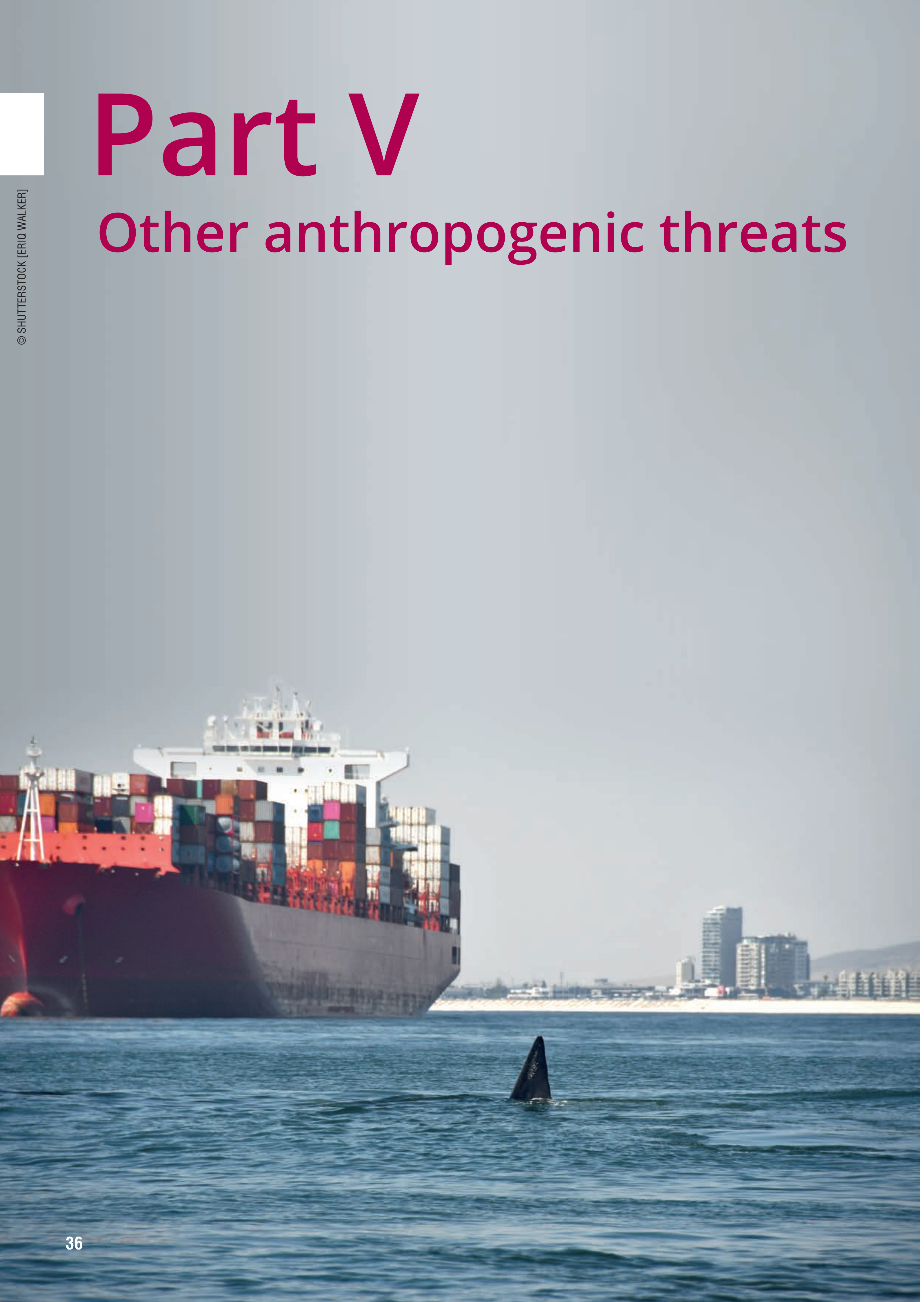

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Part V

Other anthropogenic threats

Efforts to **re-whale the ocean** are facing significant obstacles, not only due to the impacts from climate change as highlighted already, but also as cetaceans are under immense pressure globally from wide range of other anthropogenic threats including ocean vessels, entanglement and bycatch, environmental pollution, whaling and hunting, offshore developments and underwater noise. These persistent dangers are exacerbating the stresses caused by climate change, further compounding the negative impact of human activities on cetaceans. Addressing these threats would allow whale and dolphin populations to recover and build their resistance to current and future climate impacts. Governments and industry must take urgent action to mitigate or remove these harms to lessen the compounded impacts of climate change and human activities on individual animals and their populations. Acknowledging and addressing these principal anthropogenic threats would assist us to **re-whale the ocean** and allow cetaceans to return the benefit to us through climate and biodiversity gains.

OCEAN VESSELS

SNAPSHOT: WHAT ARE VESSEL STRIKES?

A vessel strike occurs when a whale or dolphin that is at or near the water's surface is hit by any part of a vessel. These are sometimes referred to as 'ship strikes', although not all collisions are with large ships. Cetaceans need to surface regularly to breathe, and it is often not possible to spot a whale in time for the vessel to alter its course to avoid a strike. Unfortunately, there are significant overlaps between the world's busiest shipping routes and critical whale and dolphin habitats, including their key migratory routes. Although it is challenging to quantify, it is estimated that thousands of cetaceans are killed, wounded or seriously harmed by collisions with vessels every year. For some species, such as the North Atlantic right whale, vessel strikes present one of the most significant causes of death and serious injury, threatening the population's survival and preventing species recovery.

Over 80% of the world's trade uses marine shipping to transport goods, and some of the world's busiest shipping routes bisect key marine biodiversity hotspots. The trend in many regions is towards a growth in shipping traffic. To illustrate, in parts of the Canadian Arctic, vessel traffic nearly tripled in some areas between 1990 and 2015, not only due to shipping, but also down to resource exploration/extraction and tourism[27].

In addition, shipping also negatively impacts cetaceans through noise disturbance from propellor cavitation and engine noise. Anthropogenic noise has been shown to interfere with cetaceans' ability to communicate, disrupts their foraging, and acts as a significant stressor. For example, shipping noise directly overlaps with the low-frequency acoustic communication vocalisations of baleen whales, as long-wavelength sounds can be detected over hundreds of kilometres. In addition, sound travels faster in warmer water. Acoustic data and hormone analysis of faecal matter in the Bay of Fundy in Canada following the 9/11 attacks, demonstrated how a decrease in background underwater noise from reduced shipping traffic corresponded to a decrease in stress-related hormone levels in North Atlantic right whales[66]. Behaviour changes have also been noted in narwhals due to novel noise pollution in their habitats[9].

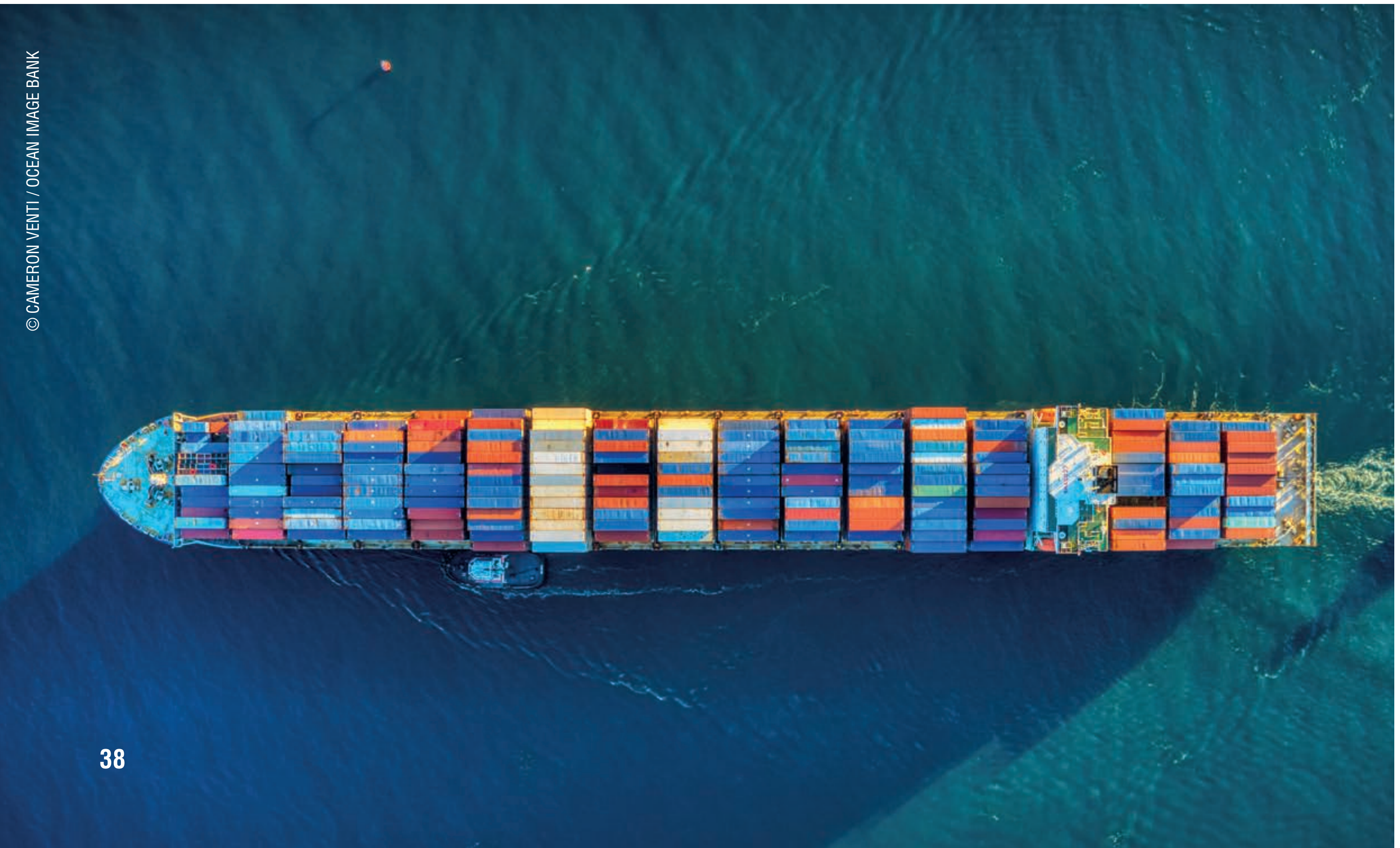
There are other potential impacts from the expansion of shipping into vulnerable areas such as the high Arctic, including from oil spills and other pollution. Black carbon (BC) is an aerosol emitted through the combustion of fossil fuels and leads to an accumulative positive climate feedback loop. BC has been shown to negatively affect the climate system, in particular the cryosphere (parts of the Earth's surface where water is frozen solid). This occurs through the light absorbing properties of BC, which affect snow and ice's albedo effect (their ability to reflect heat from the sun back into the atmosphere). BC deposits darken an area, and thus decrease how much heat is reflected, leading to increased warming and melting of ice. 20% of arctic snow and ice loss across the 20^{th} century was attributed to BC; and in Greenland, mass-loss was estimated to be at 6.8% due to BC[42]. If this feedback loop continues, and more shipping routes are established in previously unavailable areas, the twofold impact of increased risk of vessel strikes and exponential habitat degradation (via seawater freshening, loss of ice and temperature changes) are clear examples of how the compound effect of human activity and climate change is impacting marine ecosystems and species.

To reduce the risks from vessel strikes, it is essential to identify and map 'hotspots' and then take expedient action to avoid such collisions. A recent study combining whale distribution data and vessel density data of bowhead whales in the North American Arctic identified multiple hotspots for vessel strike risk. It used satellite telemetry and aerial surveys to work out the relative density of individuals alongside average 'vessel density' during the summer shipping season in recent years[27]. This kind of modelling can be used to adapt shipping routes and regulations to minimise the risk of strikes.

Some areas identified as high risk for vessel collisions with whales have implemented vessel speed restrictions or rerouting of shipping lanes to avoid critical habitats; this is being done to protect NARWs off the USA and Canada and sperm whales in the Hellenic Trench off Greece. Similar endeavours elsewhere could aid in the creation of adaptation-focused policies that are responsive to circumstances. An analysis of the migrations of Bering–Chukchi–Beaufort bowhead whales between 2009-21 noted how migration timings are already altering due to the retreat of sea ice. The authors state that this may increase the overlap of whale distributions with shipping and fisheries, especially as the Northern Sea Route and Northwest Passage become viable Pacific-Atlantic shipping routes, causing increased vessel traffic through the Bering Strait[75].

The shipping industry's environmental efforts to transition towards 'green shipping' primarily focus on reducing GHG emissions. Whilst this is essential for climate mitigation, it is important to also consider proactively limiting the industry's impact on ocean wildlife to address global biodiversity loss. There is a need for industry leaders to show innovation and develop solutions in partnership with NGOs and scientists. Reducing vessel speeds also decreases noise pollution, fuel consumption and carbon emissions, and can be rolled out alongside technical adaptations to vessel design which may help to reduce harm. As climate change is altering the course of cetacean migrations and their habitats, the shipping industry has a responsibility to reduce current risk as well as invest in monitoring and develop technological solutions to account for future alterations in vulnerable marine mammal populations and their distribution.

Shipping adaptations and regulations are the joint responsibility of industry leaders, regulatory authorities (such as the International Maritime Organisation) and States, via both central and local legislation and policy. All countries, whether landlocked or coastal, rely on shipping at some part of the supply chain for vital goods and services. State engagement with relevant regulatory bodies and international conventions is essential to ensure that the negative impact of shipping on marine wildlife is effectively mitigated.



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ENTANGLEMENTS AND BYCATCH

SNAPSHOT: WHAT ARE CETACEAN ENTANGLEMENTS?

Many people worldwide depend on fishing for both food and livelihoods. Fishing methods and fishing gear such as nets and ropes pose a significant threat to cetaceans through accidental entanglement. When the entanglement takes place in active gear, it is known as 'bycatch'. Globally, at least 300,000 cetaceans become entangled and die in fishing gear every year[39]. Whales and dolphins are air-breathing mammals and smaller species may die immediately from suffocation when entangled under water. Larger species may be left with acute or chronic injuries or towing heavy ropes and gear for extended periods, which affects their ability to feed, swim, reproduce or care for their young, compromising their health and survival.

Through the ongoing efforts of campaigners, industry and government lobbying, some mitigation measures have been put into place with varying degrees of success, such as alterations in fishing methods and establishing protected areas or seasonal closures for fishing. However, the human/cetacean interface becomes even more unpredictable when climate change triggers environmental changes that challenge temporal and spatial limitations of existing protections.

Bycatch may increase as a result of climate change as species move into new waters where protective measures are not in place. As climate change increasingly alters both cetacean and target species distribution and abundance, the challenges in monitoring and mitigating bycatch are likely to intensify. In countries where quotas are in place to limit bycatch, these levels may be exceeded as new, but unregulated, bycatch hotspots emerge, while spatial zoning restrictions for fishing vessels aimed at avoiding cetacean interactions and time/area closures may no longer align with species distribution and abundance[46.1].

It is imperative that data collection and monitoring of changes in cetacean distribution and fishery effort inform adaptive bycatch mitigation efforts. For example, surveys demonstrate that there has been a recent increase in frequency and abundance of warm water adapted cetaceans and a decrease in abundance of cold-water adapted cetaceans around the UK, due to warming water temperatures. Monitoring of stranded cetaceans in UK waters from 1990 to 2018 revealed an increase in the proportion of stranded warm water adapted species. Modelling has indicated that annual mean SST significantly increased over time around the UK in line with and comparable to the rate of change in species composition; this is likely to be caused by range shifts in cetacean prey due to climate changes already documented in the North Sea, Irish Sea and wider North Atlantic[86]. The effectiveness of efforts to reduce bycatch will be compromised if current knowledge of cetacean distributions and behaviours is inadequate.

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As a result of climate changes, new fishing activities are being investigated within important cetacean feeding grounds. A growing industry interest in the exploitation of Antarctic krill poses potential conservation threats to the large range of species who rely on this food source as well as posing risks from bycatch and entanglements with gear. In recent years, several juvenile humpback whales have been documented as entangled by a Norwegian krill boat in Antarctic waters. On the other side of the globe, an extreme marine heatwave across the California Current ecosystem during 2014-2016 led to an inshore shift of certain prey species of humpback whales. At the same time, a HAB occurred in the area, which delayed the seasonal opening of a crab fishery, to ultimately protect human health. The unfortunate result in the timing of humpbacks moving close to shore in parallel with the delay in the crab fishery opening, meant that there was a large spike in humpback entanglements in this fishing gear[25]. Both of these examples illustrate how cetacean protection needs to be adaptive to changing situations and available information, especially regarding fisheries planning, while being based upon the most up to date data and monitoring of climate change effects in the ocean.

ENVIRONMENTAL POLLUTION

Chemical contaminants are a huge environmental threat to ocean biodiversity, with whales and dolphins being particularly susceptible to accumulating toxic pollutants within their bodies. Persistent Organic Pollutants (POPs) can be bioaccumulative and are resistant to breaking down. Persistent pollutants can have long-term and devastating effects on cetaceans, such as causing cancer and reproductive disruption and compromising their immune system. Chemical pollution is a global and transboundary issue that may be exacerbated due to the highly migratory nature of many cetaceans. Climate change is affecting migratory routes of some whales and dolphins who may transport contaminants to less polluted areas or need to visit more polluted areas due to prey availability. In addition, the changes in ocean systems that have been triggered by climate change facilitate the transportation of pollutants into previously unaffected areas and can vary the way chemicals interact with organisms, altering their toxicity. The melting of polar ice is re-releasing some of the most harmful chemical pollutants produced over the last century, having previously acted as a sink for them, while mercury is seeping into the ocean and waterways from thawing permafrost. Some studies forecast a four-fold increase in POPs in Arctic waters due to climate change induced ice melting[69].

Some cetaceans are being disproportionately affected by toxins due to their prey preferences. Odontocetes (toothed cetaceans) feed at a high trophic level, so have an elevated degree of exposure risk than predators lower down the food chain due to bioaccumulation and biomagnification. Orcas are particularly vulnerable as an apex predator with a long-life span, and they have a thick blubber layer in which lipophilic POPs accumulate. As a consequence of PCB (Polychlorinated Biphenyls) exposure alone, many orca populations are now at risk of collapse. In 2016, a dead orca was found on the west coast of Scotland entangled in fishing gear, and a necropsy identified that its tissues contained 957mg/kg of PCB: one hundred times the lower toxicity threshold of 9mg/kg. Seal-eating orcas are particularly susceptible due to the bioaccumulation of pollutants in their prey. Much higher levels of PCBs and other contaminants, such as mercury, have been found in seal-eating compared to fish-eating orcas. In the Northeast Pacific, seal-eating Bigg's orca have a 10–20 times higher PCB burden than fish-eating northern resident orcas, despite sharing the same coastline. It has been noted that a switch to the consumption of other marine mammals by these orcas coincides with the overfishing of their traditional fish prey sources. Currently, only orca populations in the less contaminated regions of the Arctic and Antarctic are sustaining population growth, while some European populations are critically endangered and known to be close to extinction[84].

Further funding into the analysis of deceased individuals will help to understand both the physiological effects of POPs and how these different pollutants move from source and permeate ocean systems and food chains, including cetaceans. It is imperative that POP regulations take into account the adverse risk of climate change in exacerbating the re-distribution of pollutants and that further research and evaluation is conducted. In particular, long-term monitoring in the southern hemisphere, Arctic and Antarctic regions is required due to their role as major future sinks for persistent chemicals.

Efforts to tackle chemical pollution are being hampered by a legislation and enforcement deficit. Too many harmful pollutants are not regulated effectively enough

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to prevent long-lasting biodiversity degradation. An enforceable compliance mechanism for eliminating persistent organic pollutants (POPs) is urgently required. Immediate State support in adhering to the Stockholm Convention, investment in cleaner waste management, and restricting the production and use of all existing and emerging Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) chemicals as a group, all need to be top priority. Development of accessible and collaborative datasets on toxicological studies, such as analyses of stored tissue samples, as well as investment into research from waterways and stranded individuals will add to the global understanding of these ubiquitous pollutants. It is imperative that research into how chemical pollutants are being transported (both geographically and through the food web) due to the changes in climate is prioritised as a matter of global cetacean – and ultimately, human – health.

The supply of nitrogen-containing compounds entering the ocean grew by 80% from 1860-1990. For individual bodies of coastal water, the increase has been as high as 100-fold or more[68]. It is the responsibility of States and those involved in agriculture to prevent the influx of nutrients that lead to HABs and the deoxygenation and eutrophication of marine and freshwater habitats. This can be done by ensuring effective regulation and waste management and limiting at-source leakages and runoff of fertilisers as well as other contaminants.

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Plastic pollution is a global concern. Plastics account for up to 80% of marine litter and include abandoned, lost and discarded fishing gear (ALDFG). This pollution can have devastating effects on marine life through ingestion of plastic (directly and via trophic transfer) and entanglement. Hundreds of species across the trophic web are known to accidentally consume plastic including microplastic particles and macroplastic debris. This results in a range of acute (lethal) and chronic effects on marine life, including impacting those species who consume the affected prey species. As plastic pollution increases in the ocean, its effects on a growing range of cetacean species are being documented. In 1997, 28 of the then 75 known whale and dolphin species were reported to be impacted, either through entanglement or ingestion. This has now risen to 62 species, or 67% of the 92 recognised cetacean species[83].

WHALING AND HUNTING

Despite a commercial whaling moratorium coming into force in 1986 through the International Whaling Commission (IWC), tens of thousands of whales have been deliberately killed at sea since this date. Japan, Iceland and Norway continue to hunt cetaceans commercially. Norway objects to the moratorium, Iceland hunts under a 'reservation' to the ban, while Japan resumed commercial whaling after leaving the IWC in 2019 having previously conducted large-scale whaling under a 'special permit'. In addition to commercial whaling operations, at least 100,000 small cetaceans including narwhal, beluga, pilot whales, orca, common and bottlenose dolphins are intentionally killed every year in various countries around the world. Under various guises, and despite the demand for cetacean meat falling in many countries, whales and dolphins are slaughtered inhumanely causing immense suffering to individual animals in addition to the wider conservation concerns. The removal of any individual cetacean by hunting, especially those from threatened species, is at odds with the internationally agreed Global Biodiversity Framework which aims to reverse species and biodiversity decline. Instead of deliberately killing cetaceans, it must be an international priority to **re-whale the ocean**.

Previously, claims have been made that an increase in whale populations would lead to a reduction in fish populations, resulting in lower productivity for the fishing industry. An analysis of available evidence shows that marine mammals, including cetaceans, do not pose a threat to fisheries yield. Presumed competition between whales and humans for food has been discounted by numerous research showing that, on the contrary, the systemic overexploitation by modern fishing practices is much more likely to be causing a threat to human food security, as well as impacting cetacean welfare. Research that presents whales as disruptive to fisheries productivity have often been shown to be flawed in their approach and conclusions and are an unhelpful distraction from addressing the much larger problem of fisheries mismanagement[15.1]. Cetaceans mostly target different species and feeding ecology and behaviour of cetaceans differ to the primary species that are targeted by commercial fisheries. For example, sperm whales forage at far greater depths than any commercial fishery, and many of the great whales feed in high latitude waters in summer (for example they migrate to Antarctic waters where most of their annual consumption takes place), avoiding conflict with fisheries[88].

Similar assertions from pro-whaling nations that the culling of whales will assist the recovery of overexploited fish stocks and increase fishery yield are erroneous. Statements such as these ignore clear evidence that cetaceans can increase ocean biodiversity and benefit fish abundance. For example, it has been demonstrated that great whales are crucial ecosystem engineers who stimulate primary productivity through nutrient cycling which benefits overall fish biomass. Analysis of data from 1971–2017 shows that a marked increase in Southern right whale mortality after El Nino events is predicted to cause disruptions in the food-web and prevent an ecosystems resilience to climate change[1.] The misinformation that "whales eat all the fish" must be countered by raising awareness globally of the role that whales and dolphins play within marine ecosystems and how important it is to protect these species that are key to the structural integrity of their ecosystems[22]. Research points toward human overexploitation as the root of the problem with analyses of extensive sensitivities finding little overlap between fisheries and whale consumption in terms of prey types, with fisheries removing far more fish biomass than whales consume[22].

OFFSHORE DEVELOPMENTS AND UNDERWATER NOISE

Human activities which produce noise pollution in the ocean include shipping, seismic surveys (used to locate oil, gas and other reserves under the seabed), pile driving, explosions, acoustic alarms and other scaring devices, and high intensity sonar (for example, from miliary activities).

Loud noise can affect cetaceans in a range of ways, depending on the level and type of noise, including causing temporary or permanent hearing damage and loss, behavioural and physiological changes (such as displacement, altered behaviour and stress), masking (reducing their ability to hear and communicate), and injury (to ear structures and tissue damage from gas bubble lesions). Extreme cases can even result in the death of the whale or dolphin.

The development of marine industries impacts cetaceans in a range of ways. Offshore renewable energy developments are proceeding at pace, in response to the urgent need to address the climate crisis and reduce the use of fossil fuels. However, the various stages of these developments, including planning, construction, operation, and eventual decommissioning of a project all have the potential to affect whales. Negative impacts are experienced through the creation of loud or persistent noise, increased vessel traffic, habitat displacement, shifting existing ocean uses (such as fishing) into areas cetaceans use, food resource disruption, and the disturbance caused by general human activity in the ocean. The impacts on cetaceans from developments are often not well defined, and multiple projects developed over short time scales increase the cumulative risk of harm to these animals. Pile driving of turbine foundation bases are known to disturb and displace small cetaceans such as harbour porpoises over significant distances, and it is important that measures are adopted during the construction phases to reduce the potential for injury and displacement to individuals and populations, as well as monitoring and mitigating impacts once the sites are operational.

Therefore, it is vital that a precautionary approach is taken in the siting of all offshore developments so that areas are avoided which are critical for the survival of vulnerable whale and dolphin populations. It is also important that thorough and transparent data collection, monitoring, and risk reduction measures are adopted, with the willingness from industry and governments to adapt and change plans as needed. Technological advancements can and must co-exist with nature-based solutions including seeking to protect whales and improving their habitat. The siting, construction, operation and maintenance of offshore developments should not create a conflict with the protection of marine life.

WHAT IS THE PRECAUTIONARY PRINCIPLE?

The first widespread application of the precautionary principle was in the 1987 'Montreal Protocol on Substances that Deplete the Ozone Layer'. This principle has been subsequently utilised in other climate and environmental treaties, notably the 1992 Rio Declaration:

> *Principle 15*
> *In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.*
> **United Nations General Assembly**, 1992

There is no singular, globally accepted definition of the concept of the precautionary principle but it is widely understood and used in application to describe preventative measures or policies that err on the side of caution. While knowledge and science are constantly advancing, and our understanding of concepts such as climate change increases year on year, as does our understanding of the breadth of damage that it is causing. The precautionary principle is an admission that humanity does not currently understand the full scope of damage that has been caused by anthropogenic threats, or those that may occur in future. Because of this, we are obligated to take significant action, even in the absence of full scientific understanding[62].

Part VI
Conclusion and recommendations

In a world that is increasingly impacted by climate change and wider anthropogenic threats, the future of whales and dolphins is uncertain. This report illustrates why it is in the best interest of governments, businesses and individuals to take action and support measures that protect cetaceans due to their important roles in assisting with ecosystem functioning, biodiversity support and climate mitigation and the multiple co-benefits associated with doing so. The IPCC has analysed the threats facing the ocean at present and projected future impacts, and long advised that a precautionary approach must be taken to conservation to protect the critical environmental services the ocean provides[32].

When considering the wide-ranging and pervasive impacts of climate change on marine ecosystems and species, it is essential that urgent and meaningful action is taken to help whales and dolphins thrive by limiting global carbon emissions, implementing robust safeguards to protect the ocean from environmental harm, and removing other anthropogenic threats that whales and dolphins face.

Wherever you look, humans – deliberately or not – are making the ocean and rivers more and more perilous for whales and dolphins to live in. This report demonstrates how climate induced issues are being compounded by other anthropogenic threats facing whales and dolphins. Cumulative pressures are a major contributor to the increasing vulnerability and wellbeing of many populations. At WDC, we strongly believe that humans have the potential, passion and creativity to find solutions to the problems we are creating. We believe in the power of individuals, businesses and governments make a change to save our natural world. Whales and dolphins need people, in all their diversity, all over the world, to take meaningful action to protect the ocean and to remove the threats they face. We all have a part to play in better protecting whales and dolphin and WDC calls on you to help us **re-whale the ocean**. Together, we can safeguard the future of these critical species, and reap the climate and biodiversity benefits they bring.

WDC encourages and welcomes interest and dialogue from both State and industry stakeholders who wish to incorporate the ocean and whale and dolphin protection into their policies and plans.

WDC recommends that the following actions are taken:

CLIMATE AMBITION

Governments must:

- Reduce GHG emissions as agreed in the Paris Agreement and set ambitious new targets to draw down residual atmospheric carbon.
- Accelerate efforts to stop the expansion of new fossil fuel production and commit to a phase-out of existing fossil fuel production in order to reach net-zero by 2050.
- Ensure that the infrastructure and funding needed for the energy transition is responsibly delivered with adaptive measures to reduce impacts and restore biodiversity.
- Invest in research to enable the inclusion of ocean and wildlife population restoration into Nationally Determined Contributions, National Adaptation Plans and National Biodiversity Strategies and Action Plans.

Industries should:

- Engage with business initiatives to create linked programmes of climate mitigation and biodiversity recovery, such as Task Force on Climate-related Financial Disclosures (TCFD) and Taskforce on Nature-related Financial Disclosures (TNFD).
- Not wait for regulation but drive forward actions to meet and exceed the Paris Agreement and goals and targets of the Global Biodiversity Framework.

INTERGOVERN-MENTAL ENGAGEMENT

Governments must:

- Become an active, pro-conservation participant within intergovernmental fora that directly (IWC, CMS, and CITES etc) and indirectly (IMO, CBD, UNFCCC etc) affect cetaceans.
- Ensure appropriate regulatory and licensing systems that engages industry to comply and meet UNFCCC and biodiversity recovery targets.
- Support the expansion of Blue Carbon initiatives and include restoring wildlife populations in UNFCCC policy and processes as a climate mitigation tool.
- Work with organisations like WDC to develop national and international marine mammal policies and plans that reduce harm and allow for population recovery.
- Co-operate internationally on non-exploitative policies which prioritise climate mitigation and population recovery.

Industries should:

- Become an active, pro-conservation observer participant within intergovernmental fora that directly and indirectly affect wildlife.
- Pioneer and invest in the development of robust blue carbon initiatives that reduce harm and allow for population recovery.

EXPANDED RESEARCH AND MONITORING

Governments must:

- Make funding available to address key knowledge gaps in local, regional and global cetacean knowledge that will inform conservation strategy and policies to facilitate ecosystem recovery and mitigate climate change.
- Invest in research and monitoring in the coastal global south and small island developing states, building capacity at the local level.
- Invest in research and monitoring on the high seas, utilising contemporary and emergent conservation tools.
- Collaborate to create open access global and regional datasets that enable states and communities to contribute to, share, access and enhance their knowledge of cetaceans.
- Recognise and invest in the research of cultural population recovery of cetaceans.

Industries should:

- Partner with wildlife NGOs to invest in research programmes to address key knowledge gaps.
- Ensure that all activities which affect the marine environment, directly or indirectly have appropriate monitoring and feedback mechanisms to reduce and eliminate impact.

SHIPPING

Governments must:

- Implement mandatory measures to ensure the highest possible reduction in vessel interactions with cetaceans.

Industries should:

- Integrate shipping decarbonisation strategies with nature-recovery strategies to maximise leverage of learning and practice to the benefit of both.
- Invest in innovation to transition to vessels that are greener, more efficient, less noisy, and reduce the risks to whales and dolphins from strikes.
- Adapt vessel routes and implement appropriate speed restrictions in high-risk areas where cetaceans are known to be present to reduce the risk of strikes.
- Eliminate all at-sea discharges.
- Refuse to transport any live cetaceans or cetacean products.

POLLUTION

Governments must:

- Engage with and support the UN ‘Plastics Treaty’ development and subsequent adoption.
- Support and implement enforceable compliance systems for eliminating and responsibly disposing of POPs.
- Adhere to the terms of the Stockholm Convention and invest in cleaner waste management.
- Regulate and restrict the production and use of all existing and emerging PFAS chemicals.
- Fund, collaborate and contribute to accessible datasets on cetacean toxicology.
- Regulate to reduce inputs of plastic pollution to the environment at source with rapid transitions to less persistent and damaging alternatives.
- Regulate for standardised waste collection, recycling and processing.

Industries should:

- Invest in effective waste management for when plastic use cannot be avoided.
- Support the UN ‘Plastics Treaty’ development and subsequent adoption.
- Support and implement compliance systems for eliminating and responsibly disposing of POPs.
- Adhere to the terms of the Stockholm Convention and invest in cleaner waste management.
- Restrict the production and use of all existing and emerging PFAS chemicals throught supply chains.
- Fund, collaborate and contribute to accessible datasets on cetacean toxicology.
- Reduce inputs of plastic pollution to the environment at source with rapid transitions to less persistent and damaging alternatives.
- Advocate for and facilitate standardised waste collection, recycling and processing.

FOOD SYSTEMS

Governments must:

- Set highly precautionary and responsible catch limits for wild fish populations.
- Regulate for a rapid transition from destructive and industrial fishing practices in a just and responsible way.
- Invest in the research, development and implementation of fishing gear that reduces the risk of cetacean and other non-target species bycatch.
- Regulate for and invest in collection, processing and recycling initiatives for ALDFG.
- Transition towards more nature and climate friendly agriculture and aquaculture to reduce runoff of harmful pollutants and other substances into river and marine ecosystems.

Industries should:

- Eliminate cetacean products from human food products.
- Invest in alternative gear types that eliminate bycatch.
- Thoroughly audit supply chains and eliminate suppliers and fishing methods implicated in bycatch.
- Responsibly process ALDFG.
- Implement proactive measures that work with nature when producing food.

HUNTING

Governments must:

- Encourage countries to end all commercial whaling with immediate effect.
- Ensure all aboriginal-subsistence whaling (ASW) is in compliance with IWC ASW definitions.
- Advocate for all small cetacean hunts to come to an end.
- Ensure that all commercial trade in cetacean products is ended.

Industries should:

- Not engage with the hunting or products of hunting cetaceans throughout supply chains.

ADAPTIVE CONSERVATION POLICY

Governments must:

- Regularly review and update cetacean-linked conservation measures to ensure they align with the most up to date science on climate.
- Integrate IMMAs into all marine policy planning.
- Proactively start designating mobile MPAs that flex with cetacean movements and changes in the environment.

Industries should:

- Avoid offshore developments that overlap with IMMAs during critical periods and implement measures that reduce direct and indirect pressures on cetaceans across all sites.

ACRONYMS

AI	Artificial Intelligence
ALDFG	Abandoned, Lost or otherwise Discarded Fishing Gear
AMOC	Atlantic Meridional Ocean Circulation
ASW	Aboriginal Subsistence Whaling
BC	Black Carbon
CDR	Carbon Dioxide Removal
CITES	Convention on International Trade in Endangered Species
CMS	Convention of Migratory Species
COP	Conference Of the Parties
DA	Domoic Acid
EIA	Environmental Impact Assessment
ENSO	El Niño-Southern Oscillation
GHG	Greenhouse Gas
GPG	Global Public Good
HAB	Harmful Algal Bloom
ICMMPA	International Committee on Marine Mammal Protected Areas
IMMA	Important Marine Mammal Area
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
MHW	Marine Heatwave
MME	Mass Mortality Event
MMPATF	Marine Mammal Protected Areas Task Force
MPA	Marine Protected Area
NARW	North Atlantic Right Whale
NDC	Nationally Determined Contribution
NGO	Non Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration (US)
PCB	Polychlorinated Biphenyls
PDO	Pacific Decadal Oscillation
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
POP	Persistent Organic Pollutants
RCP2.6	Representative Concentration Pathway 2.6
RCP4.5	Representative Concentration Pathway 4
RCP8.5	Representative Concentration Pathway 8.5
SST	Sea Surface Temperature
STX	Saitoxin
UME	Unusual Mortality Event
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNWTO	United Nations World Tourism Organization.
WDC	Whale and Dolphin Conservation

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GAMES FOR WAVES

games.whales.org

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> *If we cannot save the largest animals in the world, we have little chance of saving the biosphere itself, and, therefore, of saving our own species.*
> **Sir Peter Scott** (WDC's first President)

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