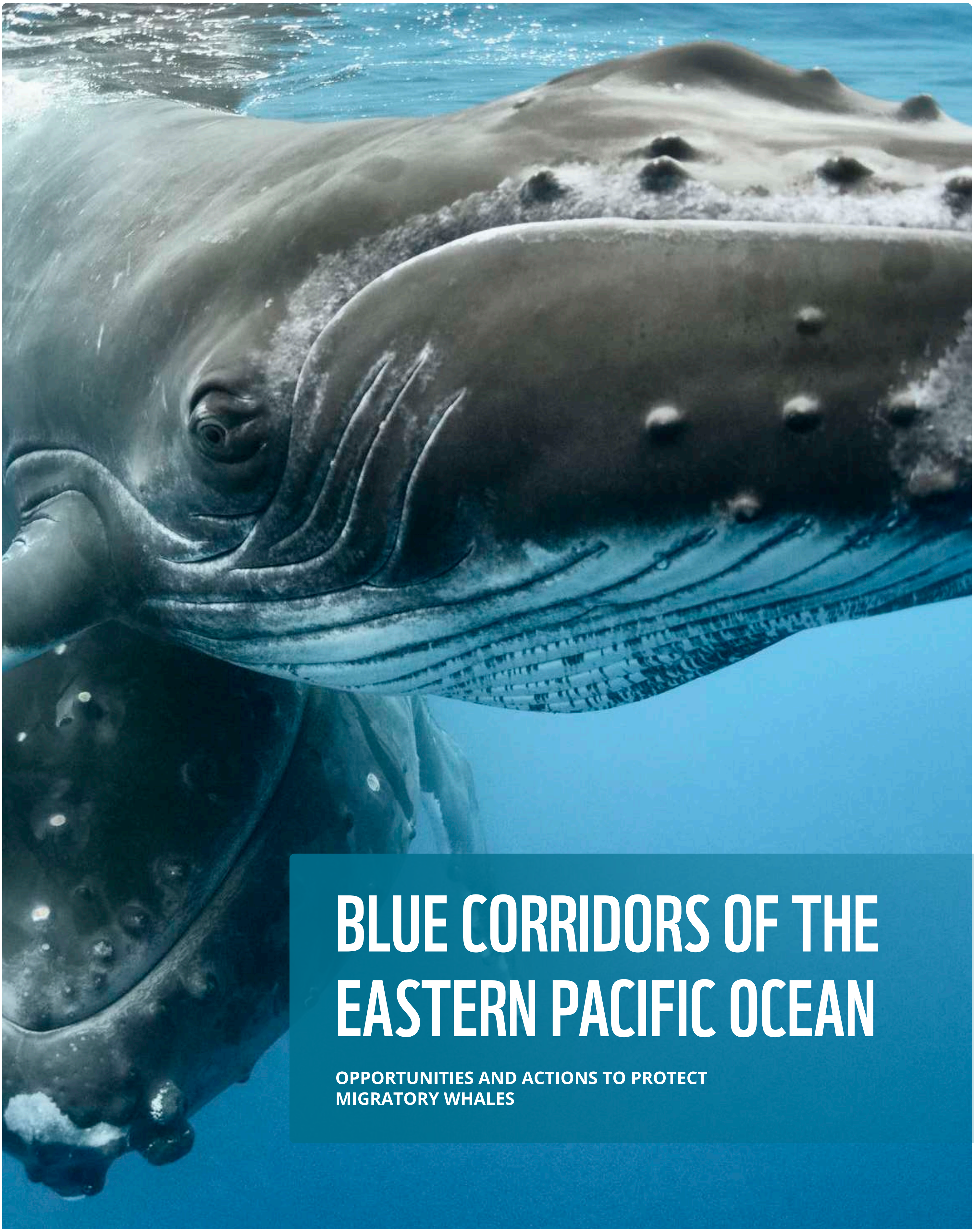


BLUE CORRIDORS OF THE EASTERN PACIFIC OCEAN

OPPORTUNITIES AND ACTIONS TO PROTECT MIGRATORY WHALES

AUTHORS:

Daniel Palacios PhD (**Oregon State University, Marine Mammal Institute**), Fernando Felix PhD (**Museo de Ballenas, Salinas, Ecuador**), Yacqueline Montecinos MPhil, Eduardo Najera PhD, Shaleyla Kelez PhD, Jorge Samaniego, Pilar Vasquez, Luis Zapata, Melanie Lancaster PhD, Chris Johnson (**WWF**), Ari Friedlaender PhD (**University of California Santa Cruz**) Cristina Castro A. PhD (**Pacific Whale Foundation**), Ester Quintana (**Emmanuel College | Simmons University, USA**), Christian Bermúdez-Rivas (**Dirección General Marítima, Centro de Investigaciones Oceanográficas e Hidrográficas del Pacífico, Colombia**), Carlos Villamil Echeverri (**Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. GIZ Colombia**), Jose Julio Casas (**Director Nacional de Costas y Mares, Ministerio del Medio Ambiente, Panama**), Maritza Sepulveda PhD (**University of Valparaiso**), Laura D. Benites Benites (**Investigadora Fundación Yubarta**), Lilián Flórez González (**Fundación Yubarta**), Lorenzo Rojas Bracho PhD (**Oceanwise**), Luis Medrano PhD (**Departamento de Biología Evolutiva. Facultad de Ciencias, UNAM**), Luis Santillan (**Universidad San Ignacio de Loyola, Lima, Perú**) Regina Aguilar Arakaki (**Oficina de Investigaciones en Depredadores Superiores - DGIRP, Instituto del Mar del Perú**), Ryan Reisinger PhD (**University of California Santa Cruz, University of Southampton**), Luis Pineda (**Ministry of Environment and Natural Resources: Government of El Salvador**), Aldo Pacheco, Isabel Ávila, Betzi Pérez-Ortega, Jorge Acevedo, Ben Haase, Roxana Margarita López, Cristina Sánchez, Natalia Botero, Elizabeth Campbell, Juan Diego Pacheco, Lili Pelayo, Romina Carnero, Joëlle De Weerdt, Miguel Pozo, Astrid Frisch, Stella Gómez, Lilián Flórez, Jorge Acevedo, Ana María González, Santiago Angulo, Paula Bueno, José Anibal Fernández (**Additional participants from the Blue Corridors workshop, Bogota, Colombia, May 2022**).

THIS REPORT USES GRAPHICS DISPLAYING SCIENTIFIC DATA ON WHALE MOVEMENTS FROM THE GLOBAL "PROTECTING BLUE CORRIDORS" REPORT.[1] WE WOULD LIKE TO THANK ALL THE CONTRIBUTORS OF SCIENTIFIC DATA TO THE GLOBAL REPORT, INCLUDING:

O. Adam (**Neurosciences Paris Saclay**) Alejandro Fernandez Ajó (**Northern Arizona University**), Artur Andriolo (**UFJF, Instituto Aqualie**), Virginia Andrews-Goff (**Australian Antarctic Division**), Salvatore Cerchio (**African Aquatic Conservation Fund**), Phillip Clapham (**Seastar Scientific**), Rochelle Constantine (**University of Auckland**), Mariano Coscarella (**CESIMAR-CENPAT**), Enrique Crespo (**CESIMAR-CENPAT**), Environment Society of Oman, Tim Collins (**Wildlife Conservation Society**), Luciano Dalla Rosa (**Universidade Federal do Rio Grande**), Mike Double (**Australian Antarctic Division**), Violaine Dulau (**Globice**), Matias Di Martino, Ken Findlay (**Cape Peninsula University of Technology**), Santiago Fernandez (**CESIMAR-CENPAT**), Raul González (**CIMAS / EsCiMar**), Claire Garrigue (**UMR ENTROPIE**), Guillermo Harris (**Wildlife Conservation Society**), Jason How (**Department of Primary Industries and Regional Development**), F. Mayer (**Cetamada NGO**), Curt and Micheline-Nicole Jenner (**Centre for Whale Research**), Christian Lydersen (**Norwegian Polar Institute**), Carina Marón (**Wildlife Conservation Society**), Bruce Mate (**Oregon State University**), Martin Mendez (**WCS**), Simone Panigada (**Tethys Research Institute**), Howard Rosenbaum (**WCS**), Rui Prieto (**University of the Azores**), Mduduzi Seakamela (**Department of Environmental Affairs**), Maritza Sepulveda (**Universidad de Valparaiso**), Monica Silva (**University of the Azores**), Roxana Schteinbarg, Mariano Sironi, Diego Taboada, Raquel Soley, Nicolás Lewin and Marcos Ricciardi (**ICB Argentina**), Federico Sucunza (**Instituto Aqualie**), Laurène Trudelle (**Neurosciences Paris Saclay**), Matthew Witt (**University of Exeter**), Judy Uhart, Marcela Uhart (**UC Davis**), Florencia Vilches and Victoria Zavattieri (**Wildlife Conservation Society**).

SPECIAL THANKS TO:

Roberto Troya, Lisa Ballance, Dermot O'Gorman, Pepe Clarke, Maggie Kinnaird, Gilly Llewellyn, Wendy Elliot, Jon Hutton, Nathalie Houtman, Heike Zidowitz, Maria Jose Villanueva, Cristina Torres, Tarsicio Granizo, Steve MacLean, Alison Cross, Leigh Henry, Rick Leck, Emily Grilly and Irina Onufrenya.

Graphic design: Catalyze (*catalyzecommunications.com*).

RECOMMENDED CITATION:

Palacios D., Felix F., Montecinos Y., Najera E., Kelez S., Samaniego J.,Velásquez P., Zapata L, Lancaster M., Friedlaender A.S., Castro C.A., Quintana E., Bermúdez-Rivas C., Cazas JJ., Villamil Echeverri C., Rojas Bracho L., Sepúlveda M., Medrano-Gonzales L., Santillan L., Aguilar Arakaki R., Pineda, L., Reisinger R., and Johnson C.M. (2023). Blue Corridor of the Eastern Pacific: Opportunities and Actions for the protection of Migratory Whales. A Technical Report. World Wide Fund for Nature (WWF).

WWF is one of the world's largest and most experienced independent conservation organizations,with over 30 million supporters and a global network active in more than 100 countries.

WWF Protecting Whales and Dolphins Initiative is a global conservation programme bringing together experts, industry, policymakers and governments to co-design solutions to safeguard our ocean giants for future generations.

WWFWHALES.ORG

CONTENTS

ABBREVIATIONS AND ACRONYMS

ABNJ	Areas Beyond National Jurisdiction (including both the High Seas and the seabed Area)
AIS	Automatic Identification System
ALDFG	Abandoned, lost or discarded fishing gear
APMs	associated protective measures
ArcNet	Arctic Ocean Network of Priority Areas for Conservation
BBNJ	Biodiversity Beyond National Jurisdiction
CBD	Convention on Biological Diversity
CCAD	Central American Commission for Environment and Development
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMAR	Eastern Tropical Pacific Marine Corridor
CMS	Convention on the Conservation of Migratory Species of Wild Animals
COP	Conference of the Parties
CPPS	Permanent Commission of the South Pacific
DOM	Dynamic ocean management
EBSA	Ecologically or biologically significant area
EEZ	Exclusive economic zone
FAO	Food and Agricultural Organization
GES	Good environmental status
GGGI	Global Ghost Gear Initiative
IATTC	Inter-American Tropical Tuna Commission
ICRW	International Convention for the Regulation of Whaling
IMMA	Important Marine Mammal Area
IMO	International Maritime Organization
INGO	international non-government organization
IOTC	Indian Ocean Tuna Commission
ISA	International Seabed Authority
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
KBA	Key Biodiversity Area
MEPC	Marine Environment Protection Committee
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NOAA	National Oceanic and Atmospheric Administration
OECM	Other Effective Area-based Conservation Measures
PARCA	Environmental Plan for the Central American Region
PSSA	Particularly Sensitive Sea Area
RFMO	Regional fisheries management organization
SPRFMO	South Pacific Regional Fisheries Management Organization
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNFCCC	United Nations Framework Convention on Climate Change

KEY MESSAGES

01

BLUE CORRIDORS ARE CRITICAL OCEAN HABITATS FOR MIGRATORY MARINE SPECIES

Whales rely on critical ocean habitats – areas where they feed, mate, give birth, nurse young, socialise or migrate – for their survival. "Blue corridors" are movement routes for marine megafauna such as whales among different but ecologically interconnected areas essential to their survival.

02

THE EASTERN PACIFIC OCEAN IS A HUB FOR WHALE SUPERHIGHWAYS

From the Bering Strait south to the temperate and tropical Pacific to the Antarctic Peninsula, productive oceanographic conditions, features and currents support a diversity of whale populations and their blue corridors, some spanning thousands of kilometers.

03

WHALES CONTRIBUTE TO OCEAN HEALTH, BUT FACE THREATS WITH CUMULATIVE IMPACTS

Growing evidence shows whales play a critical role in maintaining ocean health and our global climate, all while contributing to a global economy through tourism revenue. Yet, entanglement in fishing gear (bycatch, ghost gear), ship strikes, chemical and underwater noise pollution, loss of habitat and climate change are impacting whales, their prey and their habitats.

04

URGENT COOPERATION IS NEEDED TO SAFEGUARD WHALE POPULATIONS TO RECOVER AND THRIVE

From local to regional to international levels, local communities, science, civil society, industry, states and intergovernmental bodies have a role in safeguarding whale migration, mitigating threats and co-designing solutions. The joint declaration on the "Americas Protection for the Ocean" during the ninth Summit of the Americas is a crucial first step to conserve and protect 30 per cent of regional seas by 2030.

WHALES OF THE EASTERN PACIFIC OCEAN

Whale illustrations © Uko Gorter

BLUE WHALES

(Balaenoptera musculus)

IUCN Status: Endangered
Population: ~5,000–15,000

Two populations inhabit the region. The California population migrates between feeding grounds off the U.S. West Coast and breeding grounds in the Gulf of California and the Costa Rica Dome, in the Eastern Tropical Pacific.[3–6] The Chilean population feeds in the fjords of northern Chilean Patagonia and migrates to breeding areas off Peru, Ecuador and the Galápagos Islands.[5,7–10]

FIN WHALES

(Balaenoptera physalus)

IUCN Status: Vulnerable
Population: ~100,000

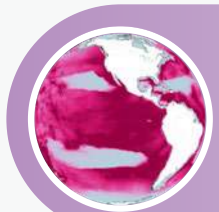
Several populations inhabit the region, including a non-migratory population found only inside the Gulf of California.[11] Other populations are found off the U.S. West Coast[12] and off the coast of South America from Chile to Ecuador.[13–20] Fin whales are frequent victims of ship strikes worldwide.

HUMPBACK WHALES

(Megaptera novaeangliae)

IUCN Status: Least concern
Population: ~84,000

The species is recovering well from commercial whaling, but is increasingly impacted by entanglement in fishing gear and ship strikes along its migrations. These threats may be especially affecting the population that breeds off Central America and feeds off the U.S. West Coast.[21–23]



SPERM WHALES

(Physeter macrocephalus)

IUCN Status: Vulnerable
Population: ~350,000

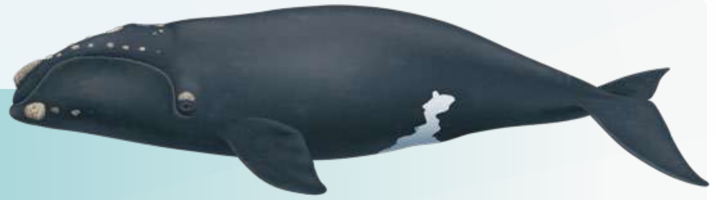
These oceanic nomads live in social matriarchal family groups in tropical and temperate waters. Groups studied at the Galápagos Islands have been re-sighted as far off as Chile and in the Gulf of California.[24]

GRAY WHALES

(Eschrichtius robustus)

IUCN Status: Least concern
Population: ~27,000

Between 2019 and 2022, 606 gray whales stranded along the west coast of North America from Alaska to Mexico. Climate change impacts on their prey is thought to be a major cause of this Unusual Mortality Event (UME). Wandering gray whales are occasionally seen in far-away areas not part of their normal distribution range, such as Hawai'i, the Mediterranean Sea, and even off Namibia.[25–29]



NORTH PACIFIC RIGHT WHALES

(Eubalaena japonica)

IUCN Status: Endangered
Population: ~350

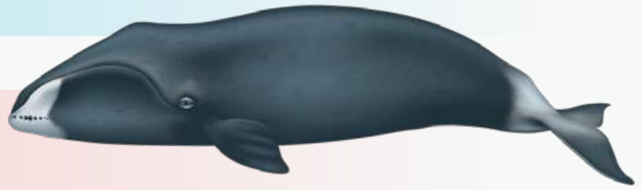
The eastern North Pacific population may only have 30 animals left, being listed as endangered. It is primarily found in the eastern Bering Sea and the Gulf of Alaska, with rare sightings reported off Washington State, southern California, Baja California, and Hawaii.[30–33]

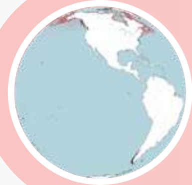
SOUTHERN RIGHT WHALES

(Eubalaena australis)

IUCN Status: Least concern
Population: ~13,600

Although southern right whale populations are recovering from commercial whaling around the world, the Chile-Peru population is not and is critically endangered at only 50 animals.[34]





BOWHEAD WHALES

(Balaena mysticetus)

IUCN Status: Least concern
Population: ~10,000

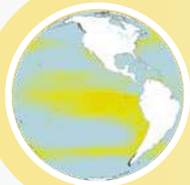
The only baleen whale endemic to Arctic and subarctic waters, bowhead whales are adapted to live in sea-ice covered waters. Strongly associated with sea ice, they are affected by climate change and associated increases in Arctic shipping.[35–37]

SEI WHALES

(Balaenoptera borealis)

IUCN Status: Endangered
Population: ~80,000

The sei whale has been referred to as 'the forgotten whale,' as it is poorly known throughout its range. They are mainly found offshore in subtropical and temperate waters. In 2015, a UME that killed at least 343 sei whales in southern Chile was attributed to a harmful algal bloom triggered by an El Niño event.[38]



BRYDE'S WHALES

(Balaenoptera brydei)

IUCN Status: Least concern
Population: ~90,000-100,000

A poorly known species, the Bryde's whale occurs throughout tropical and subtropical waters, preferring areas of elevated productivity, both nearshore and offshore, where they feed on schooling fish such as sardines. Hotspots of aggregation have been discovered in coastal waters of the Gulf of California, Panama, Ecuador, Peru and the Galápagos Islands.[39–41]

COMMON MINKE WHALES

(Balaenoptera acutorostrata)

IUCN Status: Least concern
Population: ~200,000

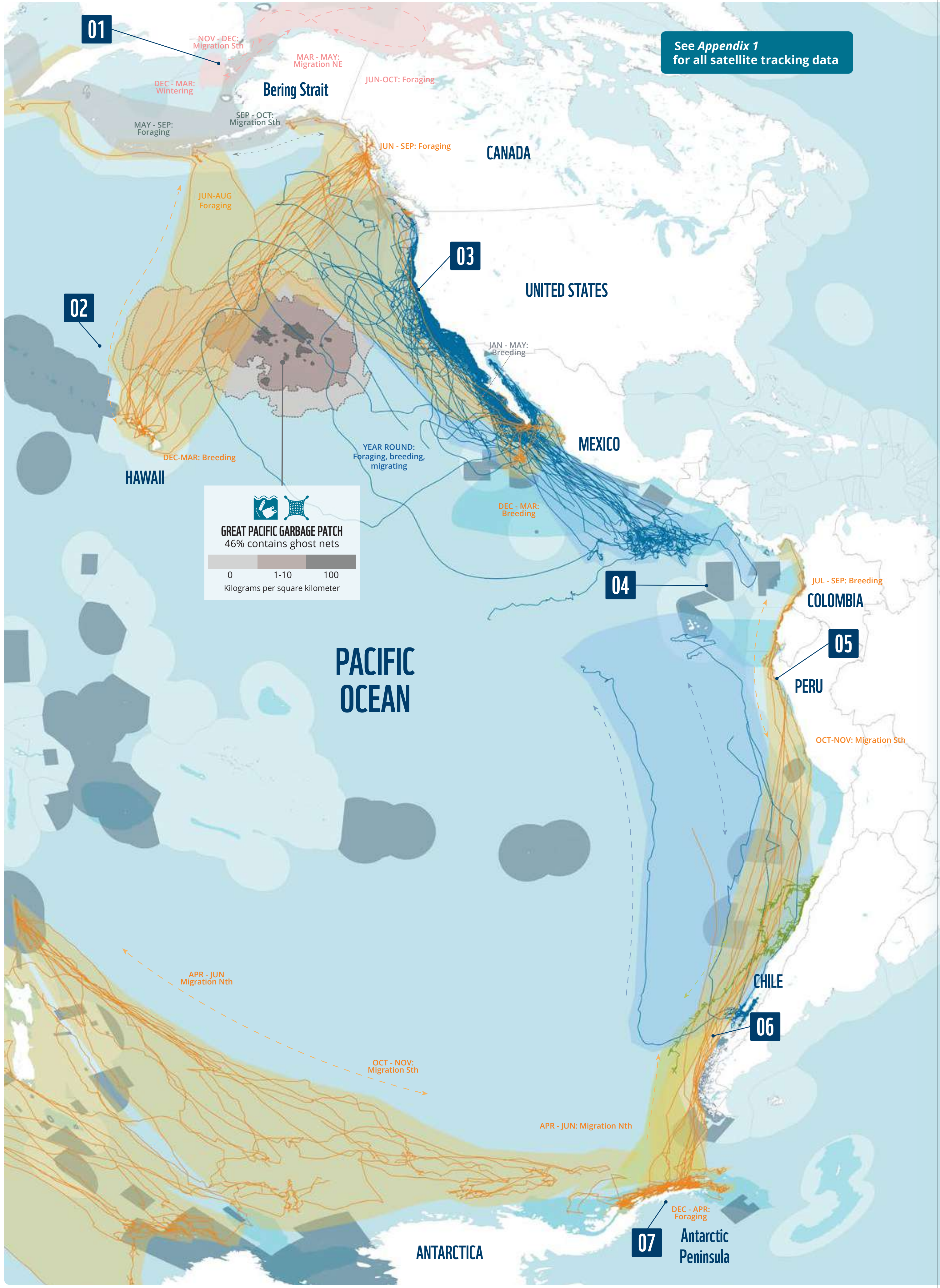
In the Eastern North Pacific, the common minke whale is widespread but not particularly common. It ranges from the Gulf of Alaska to the Gulf of California, with only a few known areas of aggregation off San Francisco Bay and in the inland waters of Washington State and British Columbia.[42–44]

ANTARCTIC MINKE WHALES

(Balaenoptera bonaerensis)

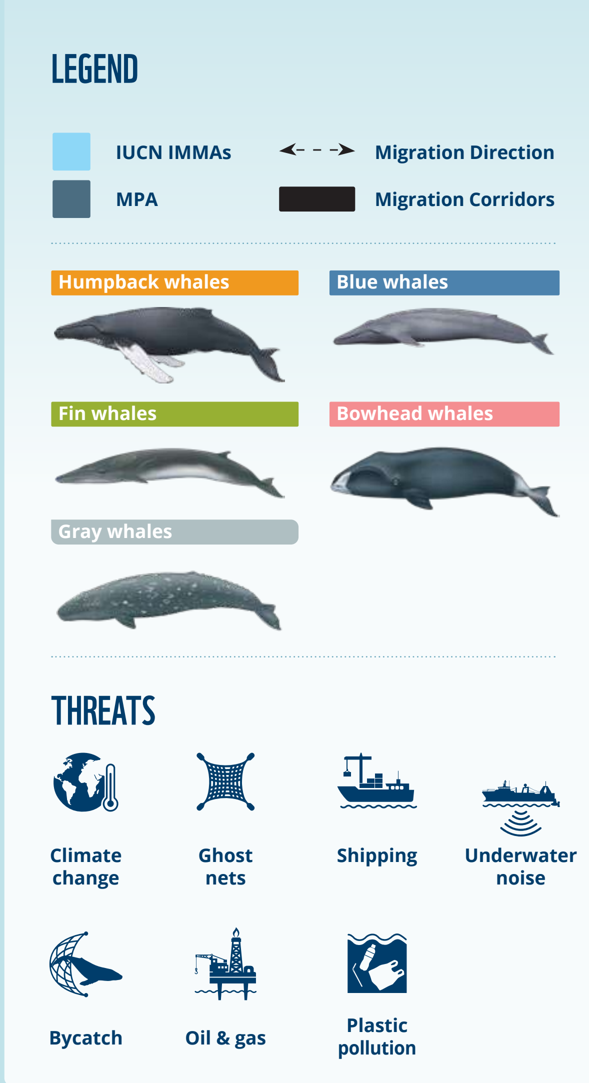
IUCN Status: Data deficient
Population: ~500,000

Primarily found in the Southern Ocean, the species is known to range into Chile, Peru and Ecuador. They are abundant in the Antarctic, especially near ice-covered regions where they feed on krill and find protection from killer whales.[45–47]



WHALE SUPERHIGHWAYS OF THE EASTERN PACIFIC OCEAN

Climate change, ship traffic, underwater noise and fishing activity are impacting whales along multiple points on their important migration routes, crucial for their survival.



01 BERING STRAIT

A key migratory corridor between the Pacific and the Arctic for millions of animals, including whales, which are contending with risks of oil spills, ship strikes, underwater noise pollution and a marine ecosystem under pressure from a warming climate. National action and international cooperation are urgently needed to better manage shipping and fisheries expansion in the region.

02 HAWAII TO ALASKA

Patterns of ocean currents lead to the formation of convergence regions, most famously the Great Pacific Garbage Patch, where abandoned, lost or discarded fishing gear, also known as ghost gear, tends to accumulate, increasing the risk of entanglement. While the Hawaiian humpback whale population has been recovering strongly, recent climate-related perturbations to the North Pacific ecosystem known as "marine heatwaves" appear to have impacted birth rates.

03 WEST COAST OF NORTH AMERICA

Migratory routes, foraging areas and breeding grounds of whales overlap with ship traffic, with fatal ship collisions the leading source of death for blue, fin, humpback and gray whales. Moreover, entanglements in a variety of fishing gear can cause mortality as well as significant injuries for these same whale species.

04 EASTERN TROPICAL PACIFIC

Whale populations from both the northern and southern hemisphere use this region as part of their migratory cycle during different parts of the year. The Eastern Tropical Pacific Marine Corridor (CMAR) initiative is a regional cooperation mechanism for the conservation and sustainable use of marine biodiversity and includes a proposed network of transboundary marine protected areas in one of the world's most important migratory routes for whales, sea turtles, sharks, rays and fish.

05 PERU

Northern Peruvian waters are part of the breeding area for southeastern Pacific humpback whales, where mothers, calves and escorts occupy shallow coastal waters for several months. To reach this breeding ground, whales have to migrate through coastal waters where gillnets and longlines represent serious threats along with ship traffic.

06 SOUTHERN CHILE

Blue whales within fjords of northern Chilean Patagonia are at high risk of ship strike and underwater noise impact, as are whales travelling through in the Magellan Strait of Chile.

07 ANTARCTIC PENINSULA

There is increasing overlap between industrial fishing for Antarctic krill and krill predators including baleen whales, penguins, seals, seabirds and fish that are foraging at the same time and place as the fishery. A new marine protected area proposal will help to conserve important Antarctic biodiversity and reduce this overlap.

ACTIONS TO SAFEGUARD BLUE CORRIDORS OF THE EASTERN PACIFIC

WWF and partners have identified actions for governments, industry and individuals to safeguard whale superhighways across the Eastern Pacific Ocean by 2030.

01

IMPLEMENT CONNECTED NETWORKS OF MARINE PROTECTED AREAS (MPAS) AND OTHER AREA-BASED CONSERVATION MEASURES (OECMS) TO CONTRIBUTE TO THE GLOBAL 30X30 TARGET

01 Support the "Americas Protection of the Oceans" joint declaration to implement networks of MPAs and OECMs in the Eastern Pacific, with the goal of protecting or conserving at least 30% of the ocean by 2030, as well as "contributing to ecological connectivity in the region protecting essential habitats and migratory routes on a regional scale for marine mammals."

02 Support for the Global Oceans Treaty at the United Nations (BBNJ) to implement effective ocean management and cooperative arrangements both within and between international and national waters, informed by IUCN Important Marine Mammal Areas and other data sources.

03 Support the full, effective and equitable participation of Indigenous Peoples and local communities in design and implementation of MPA networks and OECMs.

04 Identify and implement innovative dynamic and seasonal ocean management measures across critical habitats.

05 Finalise the CMAR commitment in the Eastern Tropical Pacific, to include an effective network of MPAs across national boundaries of neighboring countries (Costa Rica, Panama, Colombia, Ecuador and Mexico).

06 Implement marine spatial planning and cetacean conservation as part of planned management efforts within the Central American Coastal Large Marine Ecosystem (PACA).

07 Support the proposed Antarctic Peninsula MPA (Domain 1) at the Commission for the Conservation of Antarctic Marine Living Resources, restricting industrial krill fishing in key foraging habitat.

08 Support ArcNet's[48] ocean-scale ambitions and contribute to the establishment and effective management of a network of protected and conserved marine areas across the Arctic Ocean including for the Bering Strait region.

02

THROUGH COOPERATIVE EFFORTS, REDUCE CUMULATIVE THREATS

01 Work to achieve zero whale entanglements by fisheries.

02 Reduce plastic and other pollution including supporting the new UN Plastics Treaty.

03 Eliminate and clean up ghost gear including supporting the Global Ghost Gear Initiative.

04 Reroute shipping lanes away from critical whale habitats including seasonal migration areas where possible. At the International Maritime Organization (IMO), implement a Traffic Separation Scheme (TSS) on the coasts of Peru and establish an Area to Be Avoided (ATBA) surrounding the Diomede Islands in the Bering Strait.

05 Set speed restrictions to 10 knots for vessels of 65 feet and greater, and in line with navigational safety needs, when whales are using corridors to reduce ship strike risk and underwater noise pollution.

06 Enhance requirements for reporting incidences of ship-whale collisions at the IMO and to the IWC.

03

INVEST IN WHALES FOR A THRIVING OCEAN:

01 Invest in and integrate the ecological role of whales into global and national climate and biodiversity policies so populations can thrive.

02 Support large-scale regional collaborative research to inform policy recommendations as part of the UN Decade of Ocean Science.

03 Support regulated and safe whale watching practices through investment in capacity building of tourism operators, contribute to citizen science programs and provide legal support for community-based businesses to obtain necessary permits for operation according to national legislations.

04 Support community-based disentanglement networks to implement 'first responders' to assess and facilitate whale entanglement incidences safely.

05 Strengthen whale stranding networks, to respond to stranding events and improve our understanding of the causes of mortality.

© Chris Johnson / WWF-Aus

© Darren Jew

INTRODUCTION

THE EASTERN PACIFIC OCEAN – A HUB FOR MIGRATORY WHALES

Our ocean is dynamic and interconnected, from the surface to the seafloor and from the coasts to the high seas. This connectivity plays a critical role to a healthy ocean. The focus of this report is the Eastern Pacific Ocean where we explore growing risks and conservation opportunities for whales undertaking oceanic migrations over thousands of kilometers, navigating the seas across the Bering Strait, the west coast of North America to Central America and the tropical Pacific to the Antarctic Peninsula in the Southern Ocean, to name a few. Its productive oceanographic conditions, features and currents support a wealth of great whale populations.[49]

© Chad Graham / WWF-Canada

The Bering Strait connects the Arctic Ocean to the Pacific Ocean. Each year it hosts immense seasonal migrations of more than one million marine predators, including bowhead, beluga and gray whales, seals and walrus. As well as being a key migratory corridor, it is a persistent hotspot for many marine species and is one of the world's most productive marine ecosystems.[50]

The coastal waters of North America are important migratory routes and foraging areas for species including gray, blue, humpback and fin whales. Blue whales move between the Eastern Tropical Pacific and the California Current System or Gulf of Alaska, but probably feed year-round, targeting ephemeral, dynamic concentrations of krill.

The Eastern Tropical Pacific extends from the Gulf of California, Mexico to central Peru.[51,52] It is considered one of the most productive oceans in the world, with a biological richness that provides significant ecosystem services. For example, commercial fisheries (food production) are valued at approximately $2 billion per year in this region, and other significant economic benefits include carbon storage and tourism. [51,52]

The coastal marine ecosystems of Chile are among the most productive. The Gulf of Corcovado is currently considered the largest feeding ground for blue whales in the southern hemisphere, where other baleen whale species such as humpback, sei and fin whales are frequently observed feeding or migrating. The Antarctic Peninsula is an important foraging area for whale species including humpback, minke, fin, southern right and blue whales.[53] Here, they feed on Antarctic krill, their main prey in the Southern Ocean.

In June 2022, at the Ninth Summit of the Americas in Los Angeles,[54] the joint declaration of "Americas for the Protection of the Ocean" was signed by the governments of Chile, Canada, Colombia, Costa Rica, Ecuador, Mexico, Panama, Peru and the United States.[55] The main objective of the coalition is creating a space for collaboration, cooperation and coordination at a political level to design and implement Marine Protected Areas and Other Effective Area-Based Conservation Measures in the Pacific, with the goal of protecting or conserving at least 30% of the ocean by 2030, as well as "contributing to ecological connectivity in the region protecting essential habitats and migratory routes on a regional scale for marine mammals". It recognises that our "*ocean covers three quarters of our planet, supplies nearly half the oxygen we breathe, absorbs over a quarter of the carbon dioxide we produce, plays a vital role in the water cycle and the climate system, and is an important source of our planet's biodiversity and of ecosystem services. It connects our populations and markets and forms an important part of our natural and cultural heritage. It contributes to sustainable development and to sustainable ocean-based economies, as well as to poverty eradication, food security and nutrition, maritime trade and transportation, decent work, and livelihoods.*" [55]

"BLUE CORRIDORS" ARE MIGRATION SUPERHIGHWAYS FOR MARINE MEGAFAUNA SUCH AS WHALES.

Humpback Whale illustration © Uko Gorter

WHALE SUPERHIGHWAYS BENEFIT NATURE AND PEOPLE

In 2022, drawing on the latest scientific evidence from years of satellite tracking data and knowledge from the global research community, WWF and its partners – including University of California Santa Cruz and Oregon State University, University of Southampton and many others – compiled over thirty years of data to map routes of migratory whales as they move through international waters, national seas and coastal areas, between key breeding and foraging locations.

The global report - *Protected Blue Corridors* – covered a range of ocean areas to identify where migratory routes and key areas overlap with a range of emerging and cumulative threats from human activities.

Cetaceans (whales, dolphins and porpoises) rely on different critical ocean habitats – areas where they feed, mate, give birth, nurse young, socialise or migrate – for their survival.[56] In their simplest and narrowest sense, "blue corridors" are migration superhighways for marine megafauna such as whales. More broadly, the term encompasses the idea that marine megafauna move among different but ecologically interconnected areas, and that movement between critical habitats is essential to their survival.

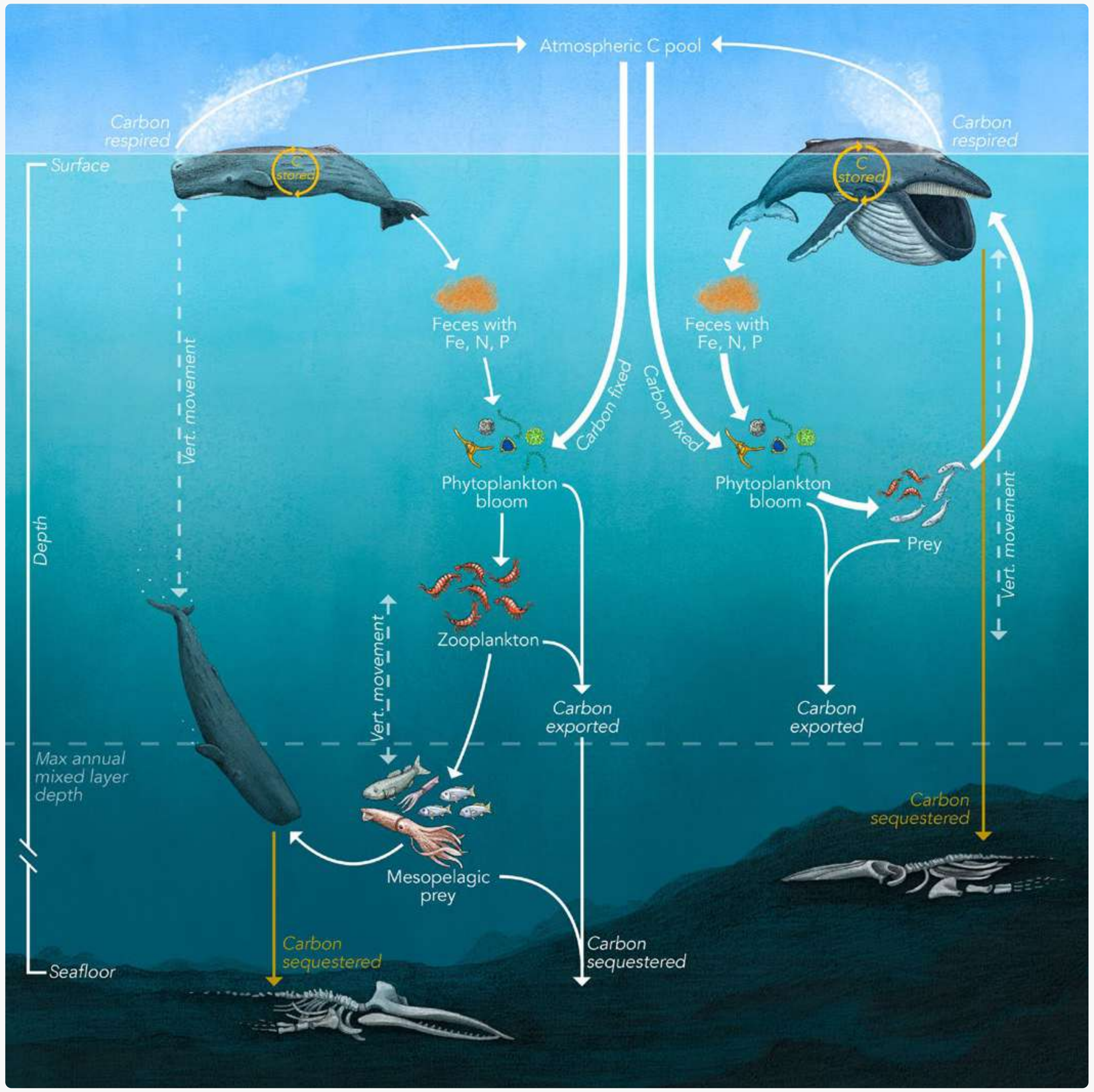
Scientific evidence gathered over the past decade bears this out, showing that whales play an essential role in the overall health of our oceans and, by extension, the whole planet.[57,58] Growing evidence shows that whales help to regulate the climate by capturing carbon throughout their lifetime – one whale captures the same amount of carbon as thousands of trees – but their excrement also fertilizes our oceans, which in turn fuels phytoplankton, microscopic plants that produce more than half of the world's oxygen. This contribution to ocean productivity has benefits for nature, for people and their livelihoods, and for major global industries. Whales contribute to maintaining the food web of the commercial fishing industry, for example, which is valued at more than US$150 billion.[57]

Economists have sought to quantify the numerous benefits whales offer nature and people. The International Monetary Fund estimates the value of a single great whale at more than US$2 million, that totals more than US$1 trillion for the current global population of great whales. The global whale-watching industry alone is valued at more than US$2 billion annually.[57] But whales have intrinsic value, and our oceans need thriving populations. The benefits they provide – from capturing carbon to enhancing marine productivity – only strengthen the case for protecting them.[58,59]

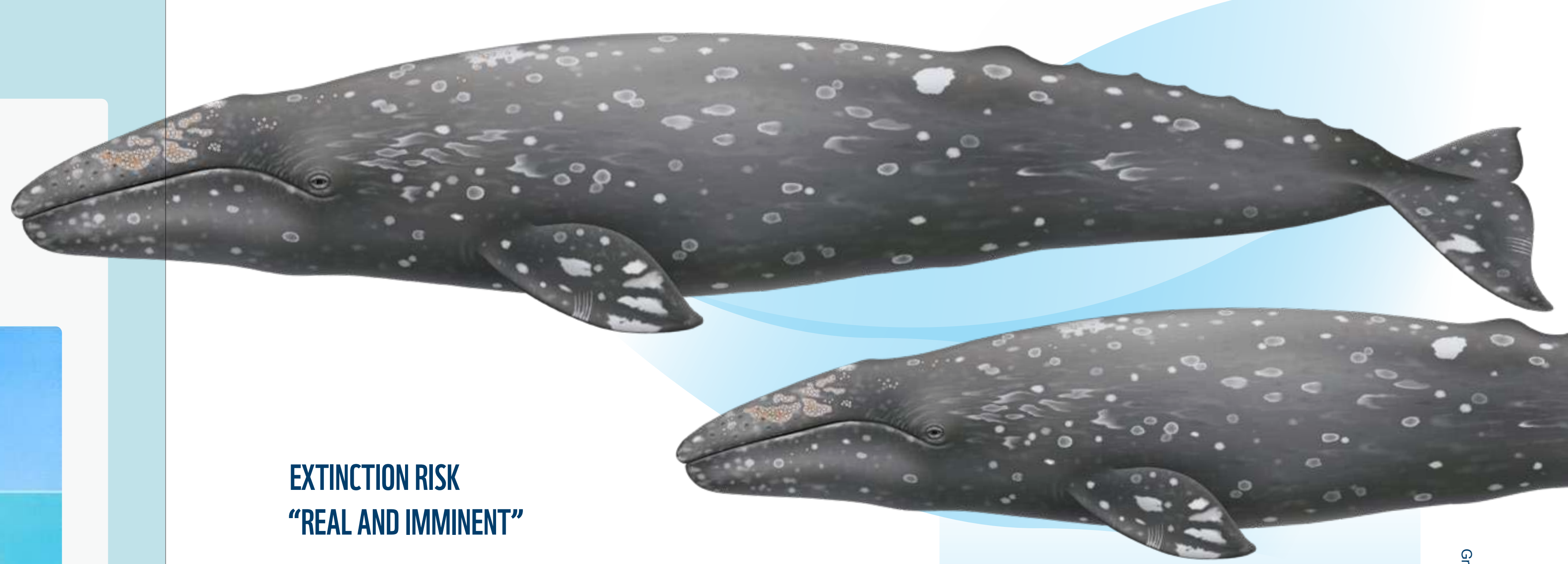
FIGURE 1

WHALE PUMP

An illustration of great whales' direct and indirect nutrient and carbon cycling pathways.[59]



SCIENTIFIC EVIDENCE GATHERED OVER THE PAST DECADE BEARS THIS OUT, SHOWING THAT WHALES PLAY AN ESSENTIAL ROLE IN THE OVERALL HEALTH OF OUR OCEANS AND, BY EXTENSION, THE WHOLE PLANET.[57,58]



Gray Whale illustration © Uko Gorter

EXTINCTION RISK "REAL AND IMMINENT"

If healthy whale populations are an indicator of overall marine ecosystem health, there is growing concern. A third of the world's cetaceans are now classified by the International Union for Conservation of Nature (IUCN) as Threatened, meaning they have either a high, very high or extremely high risk of extinction in the wild. Six out of the 13 great whale species are classified as Endangered or Vulnerable, even after decades of protection after the commercial whaling moratorium.[60] The extinction risk to whales is "real and imminent" according to more than 350 scientists and conservationists – who signed an open letter in 2020 calling for global action to protect cetaceans from extinction.[61] More than half of all cetaceans are of conservation concern. They join small cetaceans such as the critically endangered vaquita porpoise, only found in the upper Gulf of California, Mexico; the species sits poised on the verge of extinction, with a minimum number remaining to be eight with two calves.[62]

THREATS TO WHALES ARE INCREASING

During the 20th century, nearly 3 million whales were commercially harvested, driving many species to the brink of extinction.[63] While a significant reduction of commercial whaling has allowed some populations to bounce back, new threats have emerged [64,65] that make the migratory routes of whales and other marine species increasingly difficult and dangerous to navigate. As the threats to whales evolve, our conservation approach must evolve with them across their entire range.

In countless areas around the globe, cetaceans are under threat from human activities. An estimated 300,000 cetaceans are killed each year as a result of fisheries bycatch,[66] while populations are impacted from increasing ship traffic,[67,68] underwater noise,[69] pollution [70,71] and loss of important habitats including as a result of climate change.[72]

These threats often occur in concert and overlap with whales' critical habitats and migration routes, creating a hazardous and at times fatal obstacle course for whales travelling between breeding and foraging areas. For example, between 2019 and 2022, 606 gray whales have stranded along the west coast of North America from Alaska to Mexico and have been classified as an Unusual Mortality Events (UME).

DURING THE 20TH CENTURY, NEARLY 3 MILLION WHALES WERE COMMERCIALLY HARVESTED, DRIVING MANY SPECIES TO THE BRINK OF EXTINCTION.[63]

Although research is inconclusive, ongoing concerning factors include climate change impacts on Arctic sea ice and availability of key prey for gray whales. According to a U.S. National Oceanic and Atmospheric Administration assessment released in October 2022, the most recent count put the population at 16,650 gray whales – down 38% from its peak during the 2015-16 period.[73,74]

As this report emphasizes, it is not just one threat that is causing significant decline in whale populations (as well as the health of remaining individuals); it is many threats, working together, that are causing cumulative and often deadly impacts.

OPPORTUNITIES TO IMPLEMENT NEW APPROACHES TO WHALE CONSERVATION

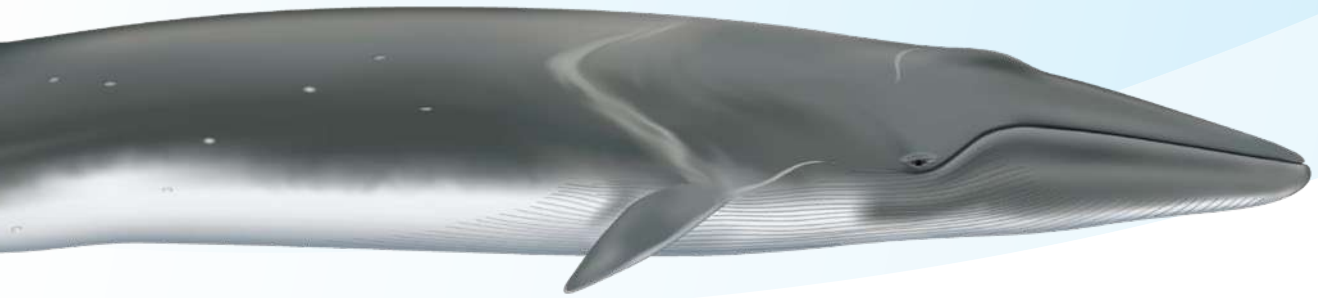
This analysis focuses on the Eastern Pacific Ocean, from the Bering Strait to the Antarctic Peninsula. It draws on a conservation practice already widely used on land known as "connectivity conservation", but applies it to the world's seas and through a singular focus on whales, which are considered "umbrella species" – that is, representatives of the biodiversity of the complex ecosystems they inhabit. Put simply, this means conserving whales across their entire range will also help many other species.[56]


© Richard Barrett / WWF-UK

Connectivity conservation is a concept that recognizes that species survive and adapt better when their habitats are managed and protected as large, interconnected networks. The IUCN World Commission on Protected Areas Connectivity Conservation Specialist Group, and its Marine Connectivity Working Group, define connectivity conservation as the action of individuals, communities, institutions and businesses to maintain, enhance and restore ecological flows, species movement and dynamic processes across intact and fragmented environments. In essence, this is what our report seeks to achieve, and in applying these lessons learned on land to our seas, protect migratory whales into the future.

Protecting the *Eastern Pacific Blue Corridors* for whales requires a holistic strategy, one that engages multiple international and regional organizations responsible for formulating policies across a range of areas and industries, from fisheries to shipping, among them the International Whaling Commission (IWC) , the International Maritime Organization (IMO), regional fisheries management organizations, and international conservation agreements such as the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Commission for Environmental Cooperation.

THE HIGH SEAS MAKE UP TWO THIRDS OF THE EARTH'S OCEAN, YET NO OVERARCHING TREATY EXISTS TO CONSERVE AND RECOVER VULNERABLE SPECIES AND THEIR ECOSYSTEMS, DESPITE THEM SPENDING UP TO THREE-QUARTERS OF THEIR TIME IN THESE WATERS.[75]



Fin Whale illustration © Uko Gorter

TYPES OF ECOLOGICAL CONNECTIVITY

The unimpeded movement of species and the flow of natural processes that sustain life on Earth.[84,85]

ECOLOGICAL CONNECTIVITY FOR SPECIES:
The movement of populations, individuals, genes, gametes and propagules between populations, communities and ecosystems, as well as that of non-living material from one location to another.

FUNCTIONAL CONNECTIVITY FOR SPECIES:
A description of how well genes, gametes, propagules or individuals move through land, freshwater and the ocean.

STRUCTURAL CONNECTIVITY FOR SPECIES:
A measure of habitat permeability based on the physical features and arrangements of habitat patches, disturbances and other land, freshwater or seascape elements presumed to be important for organisms to move through their environment. Structural connectivity is used in efforts to restore or estimate functional connectivity where measures of it are lacking.

ECOLOGICAL CORRIDORS:
A clearly defined geographical space that is governed and managed over the long term to maintain or restore effective ecological connectivity. The following terms are often used similarly: "linkages", "safe passages", "ecological connectivity areas", "ecological connectivity zones" and "permeability areas".

ECOLOGICAL NETWORK (FOR CONSERVATION):
A system of core habitats (terrestrial or marine protected areas, OECMs and other intact natural or semi-natural areas), connected by ecological corridors, which is established, restored as needed and maintained to conserve biological diversity in systems that have been fragmented.[86]

OECM
(OTHER EFFECTIVE AREA-BASED CONSERVATION MEASURE):
A geographically defined area, other than a protected area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the in situ conservation of biodiversity with associated ecosystem functions and services and, where applicable, cultural, spiritual, socio-economic and other locally relevant values are also conserved (IUCN WCPA, 2019).[87]

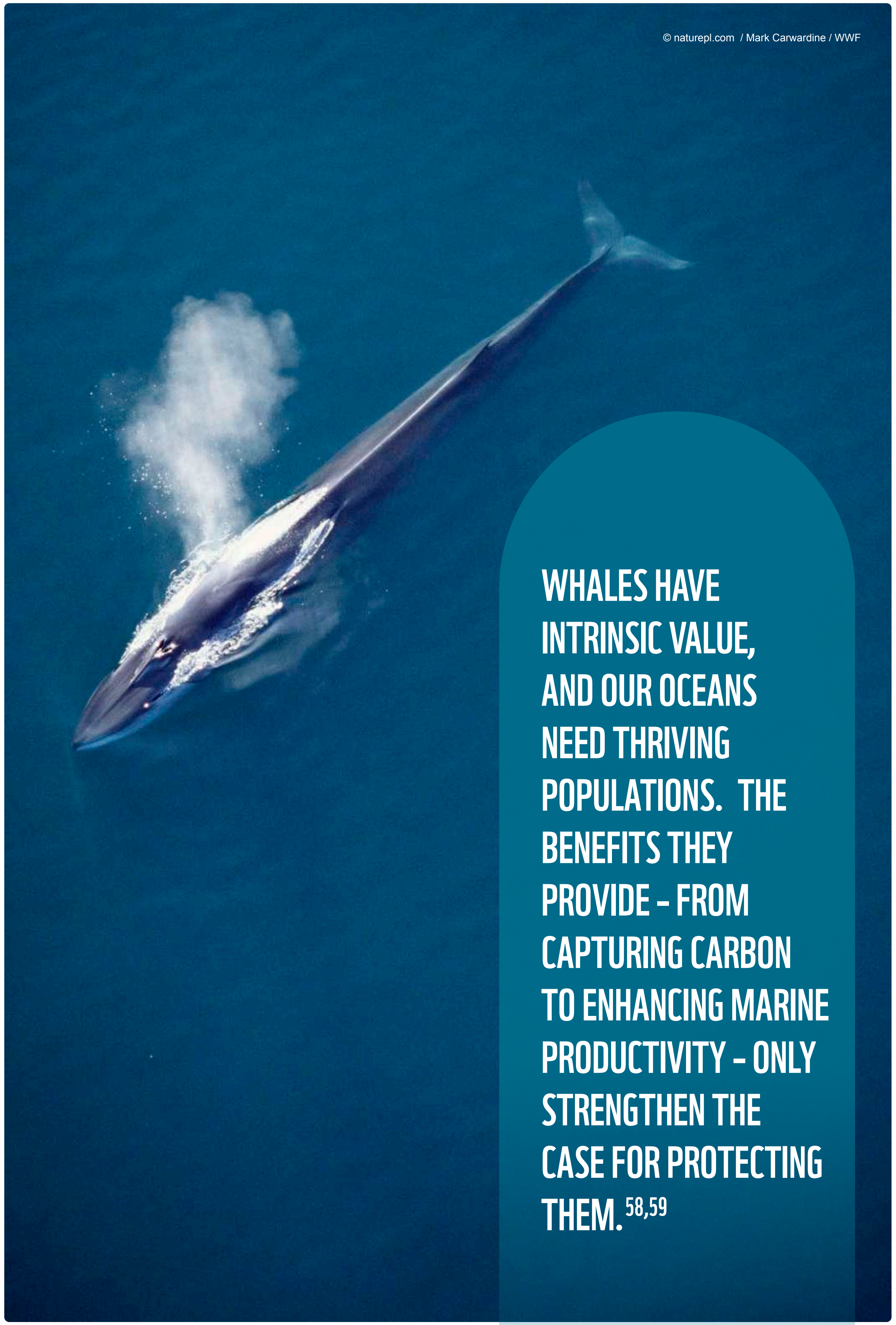
PROTECTED AREA:
A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.[85] Ecological corridors in marine environments may connect marine protected areas (MPAs) or other key marine, coastal and estuarine habitats.[88]

The high seas, or Areas Beyond National Jurisdiction (ABNJ), make up two thirds of the Earth's oceans, yet no overarching treaty exists to conserve and recover vulnerable species and their ecosystems, despite them spending up to three-quarters of their time in these waters.[75] The Global Oceans Treaty is under negotiations at the United Nations (UN) and is particularly critical to managing and reducing growing human impacts in ABNJ .[76]

Marine protected areas (MPAs) are conservation tools intended to protect biodiversity, promote healthy and resilient marine ecosystems, and provide societal benefits.[77] Today, only 8.16 per cent of the world's ocean has actively managed MPAs. However, in ABNJs it is only 1.44 per cent.[78] The call to protect and conserve 30 per cent of our ocean by 2030 through implementing networks of MPAs or Other Effective area based Conservation Measures (OECMs),[79,80] commonly known as "the 30 by 30 pledge" (30x30), was recently adopted by 196 governments as a target within the Convention on Biological Diversity's Global Biodiversity Framework.[81,82]

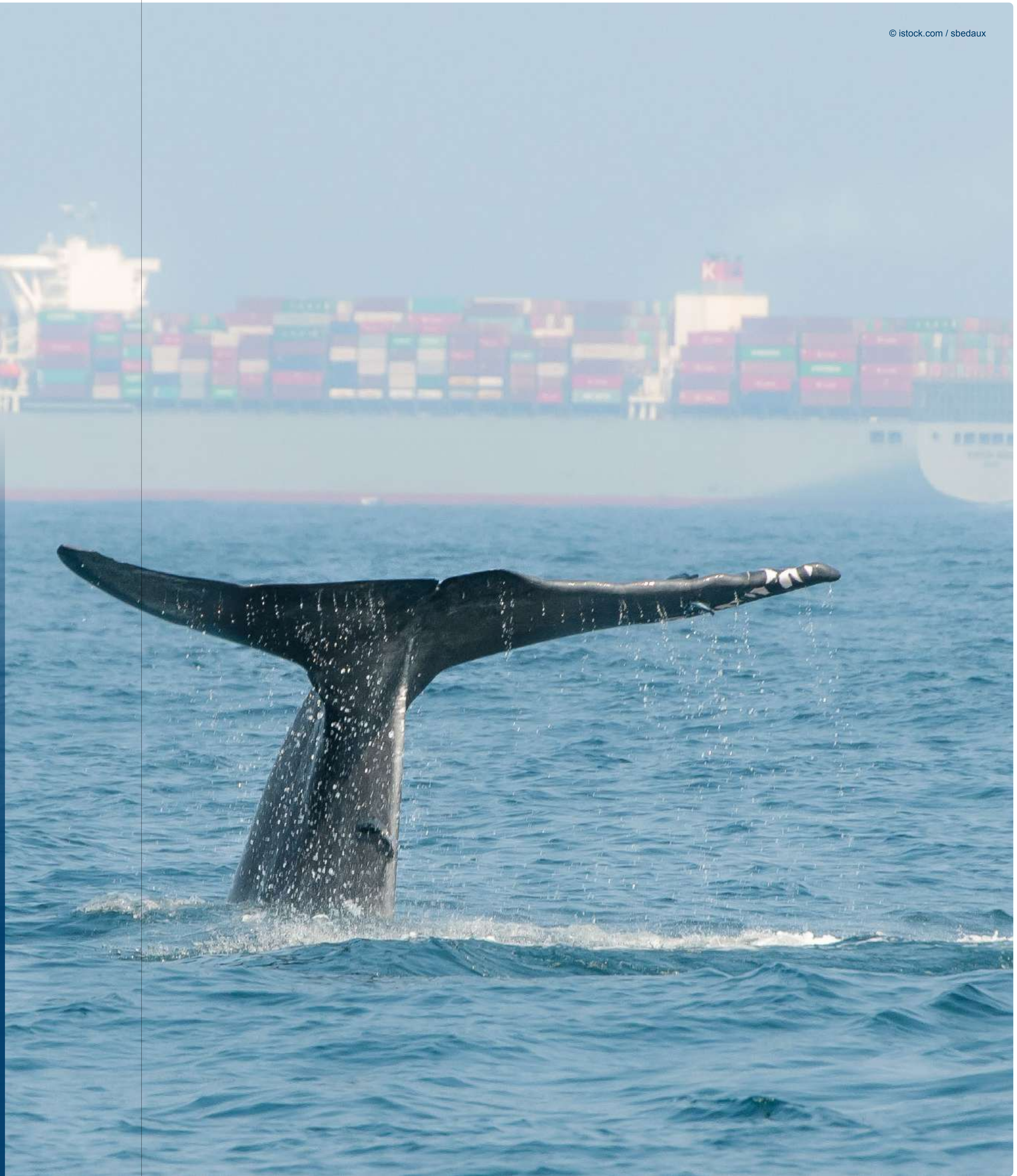
There is still much more to discover about migration of many whale populations. To help inform this work, the report identifies key conservation opportunities globally and some innovative solutions available to governments, policymakers and industry to safeguard whales, their migrations and their critical habitats for future generations.

In terms of their execution, we require a suite of responses to tackle the multiple threats, from reducing bycatch and shipping impacts in key hotspots to establishing well-connected networks of MPAs and OECMs. As some whales' migrations span across ocean basins, networks of protected areas will need to be large and potentially mobile where boundaries shift across space and time, as climate change impacts dynamic habitats and causes shifts in species range.[83] Whales' movements across jurisdictional boundaries also present opportunities for innovative transnational collaboration strategies among neighboring countries toward common conservation goals.



© naturepl.com / Mark Carwardine / WWF

WHALES HAVE INTRINSIC VALUE, AND OUR OCEANS NEED THRIVING POPULATIONS. THE BENEFITS THEY PROVIDE – FROM CAPTURING CARBON TO ENHANCING MARINE PRODUCTIVITY – ONLY STRENGTHEN THE CASE FOR PROTECTING THEM.[58,59]



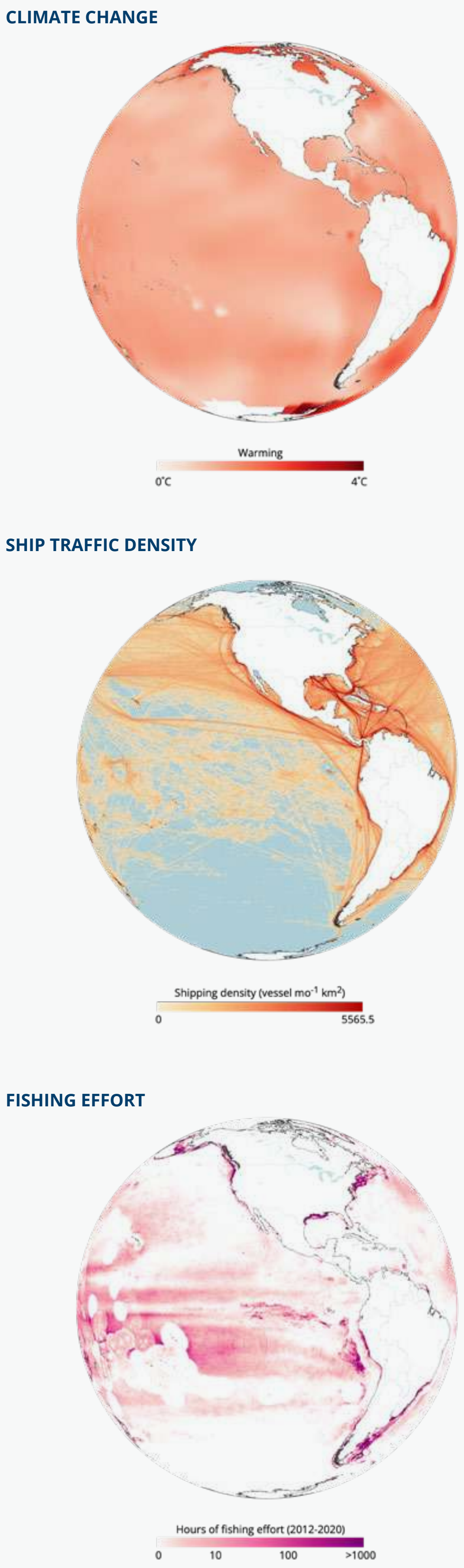
© istock.com / sbedaux

GROWING THREATS

Whales face increasing threats due to human activities in their critical habitats and migratory corridors across their entire range.[64,65] Populations are affected by increasing fishing activity, entanglement in ghost gear, ship traffic and noise pollution. Climate change and chemical and plastic pollution are impacting their habitats and prey.

FIGURE 2

Maps of some of the growing threats for whales, including climate, vessel traffic and fishing. See Appendix 2 *for more information.*



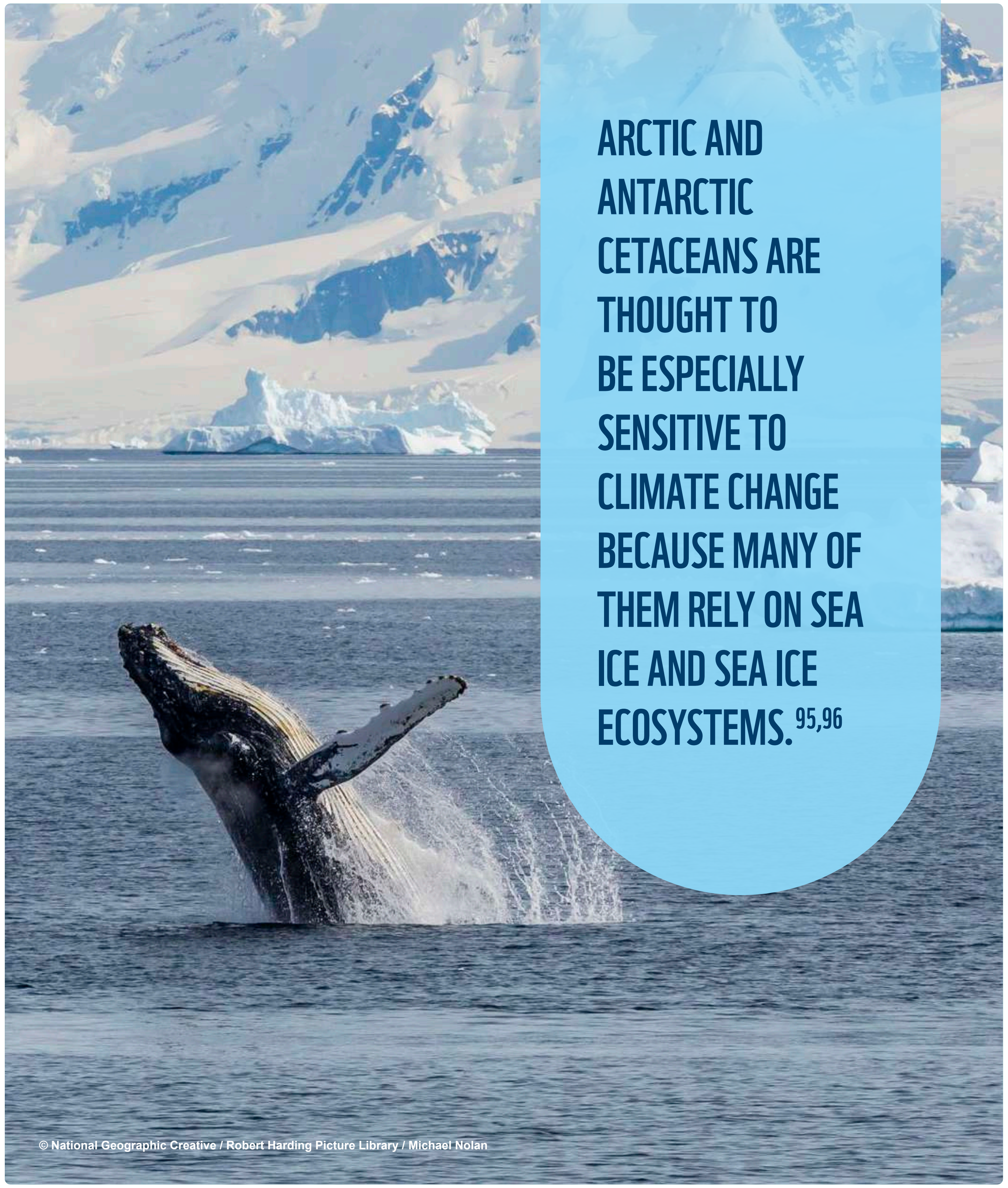
CLIMATE CHANGE IMPACTS ON WHALES AND THEIR PREY

Marine ecosystems are being severely impacted by climate change.[89,90] Marine mammals have unique ecologies with complex life cycles that make predicting their responses to climate change more difficult and, for some species, make them especially vulnerable to climate change impacts.[91,92]

Broadly, climate change affects the phenology (the timing of recurring biological events, such as migration), demography (aspects such as survival rates and calving rates) and distribution of marine vertebrates,[93] which can influence marine ecosystem structure and functioning. Shifting geographic ranges of marine species have been observed across all ocean regions.[90]

Changes in the distribution and abundance of prey is a central way in which climate change impacts whales. However, how climate change impacts the individual physiology of whales is still poorly understood.[91] Whales also may be affected by physical changes to their habitats and increased susceptibility to disease and contaminants.[94]

Arctic and Antarctic cetaceans are thought to be especially sensitive to climate change because many of them rely on sea ice and sea ice ecosystems.[95,96] The rapid decline of sea ice in the Arctic is altering habitat availability, shelter from predators and timing of important life events for endemic whales. This includes their seasonal migrations, which for bowhead and beluga (*Delphinapterus leucas*) whales in the Bering Strait, follows sea ice retreat in spring/summer and advance in autumn/winter.[97–99] Increasing frequency of marine heatwaves in the Pacific Arctic as a result of climate change may also be responsible for bowhead whales in this region foregoing their seasonal migration south and remaining in their summer feeding grounds over winter for the first time in 2018–19.[35,36] This possibly represents a major shift in migration behaviour for these whales as a result of climate change.



In the Southern Ocean, there are regional, southward shifts in Antarctic krill distribution due to ocean warming.[100] For whales feeding almost exclusively on krill – such as Antarctic blue (*Balaenoptera musculus intermedia*), humpback and Antarctic minke whales – it is likely to impose high energetic costs on migration, with effects on body condition, reproductive fitness and population abundance.[101,102] In particular, the distribution and ecology of Antarctic minke whales are directly tied to sea ice[45] where any changes that affect the quantity and quality of their habitat and food availability could be significant.[103]

Climate change will impact cetaceans in other regions too.[72] Particularly concerning is the possibility that multiple stressors will act in concert and magnify the impact of climate change long term.[104]

© naturepl.com / Tony Wu / WWF

640,000 TONNES OF FISHING GEAR ARE LEFT IN OUR OCEANS ANNUALLY.

IT CAN PERSIST IN THE MARINE ENVIRONMENT FOR UP TO 600 YEARS, CONTINUING TO CATCH AND KILL MARINE LIFE BEFORE EVENTUALLY BREAKING DOWN INTO MICROPLASTICS AND ENDING UP IN THE FOOD CHAIN.[109]

INCREASED RISK OF BYCATCH IN FISHING GEAR AND GHOST NETS

Bycatch is the accidental catch of non-target species in fishing gear leading to unintentional mortality. It is recognized as the most significant threat to the survival of marine megafauna, including marine mammal, turtle, shark and ray species and populations world-wide.[65,66]

Many international non-governmental organizations, intergovernmental organizations and national regulatory bodies realise that addressing the threat of bycatch is one of the most pressing cetacean conservation challenges of the 21st century. Bycatch of cetaceans occurs in all kinds of fishing operations, from large industrial to localised artisanal fisheries. It also occurs in most types of fishing gear. Driftnets, gillnets and entangling nets are known to cause the highest amount of cetacean bycatch. Large whales are particularly susceptible to becoming entangled in nets and ropes associated with pots and traps and fish aggregating devices, which are used to attract fish.[105]

The International Whaling Commission (IWC) launched the Bycatch Mitigation Initiative to develop, assess and promote effective bycatch prevention and mitigation measures worldwide.[105] Similarly, the Food and Agricultural Organization (FAO) has several subsidiary bodies, such as the Committee on Fisheries, that are recognizing the importance of addressing fisheries bycatch.

There is also growing awareness of the lack of effective monitoring of fishing activities at sea, which means that we know little about the true impact that fisheries have on non-target species such as cetaceans. Meanwhile, technology is moving swiftly to the point of being able to deliver cost-effective, real-time coverage of fishing activities at sea, and there is a real opportunity for Remote Electronic Monitoring of our fisheries activities. That way we better understand more about what target fish species are being caught and what species are accidentally caught in fishing gear. This move will help improve the sustainability of fishing and help bring an end to wildlife bycatch on large and small vessels.[106]

Each year, 640,000 tonnes of fishing gear are left in our oceans. Abandoned, lost or discarded fishing gear (ALDFG) – commonly called "ghost gear"[107] – accounts for a minimum of 10 per cent of all marine litter entering the oceans.[108] That's more than one tonne of fishing gear lost in the sea for every minute of the year. This type of litter can persist in the marine environment for up to 600 years, continuing to catch and kill marine life before eventually breaking down into microplastics and ending up in the food chain.[109]

A recent study estimates that 5.7 per cent of all fishing nets, 8.6 per cent of all traps and 29 per cent of all lines are lost around the world each year.[110] The Great Pacific Garbage Patch is a major ocean plastic accumulation zone in the subtropical waters between California and Hawaii. At least 46 per cent of it consists of fishing gear.[111] The impact that ghost gear entanglement has on marine megafauna is significant: a total of 76 publications highlight that more than 5,400 individuals from 40 different species were recorded as entangled in, or associated with, ghost gear.[112]

SHIP STRIKES

Between 1992 and 2012, global ship traffic increased fourfold[113] and it is projected to increase 240–1,209 per cent by 2050.[69,114] The ever-expanding shipping traffic from super-tankers and cargo vessels in whales' breeding grounds and along their migration routes results in an increased risk of ship strikes. Some of the busiest ports and channels in the world's oceans overlap with important habitats for whales.[115]

Globally, shipping poses multiple threats to whales, including deaths directly caused by vessel strikes.[68,116] Ship strikes are one of the leading causes of human-induced mortality for several whale populations around the globe, including many that are already threatened or endangered after decades of whaling.[68,117,118] Moreover, although collisions with small vessels have a lower probability of lethal injury for whales, these collisions may result on vessel damage or even risks to vessel crew who may incur injuries, or even die.[68] This situation should be given special attention in whale aggregation areas with heavy recreational vessel traffic.

SHIP STRIKES ARE ONE OF THE LEADING CAUSES OF HUMAN-INDUCED MORTALITY FOR SEVERAL WHALE POPULATIONS AROUND THE GLOBE.

© Chris Johnson

CHEMICAL, PLASTIC AND UNDERWATER NOISE POLLUTION

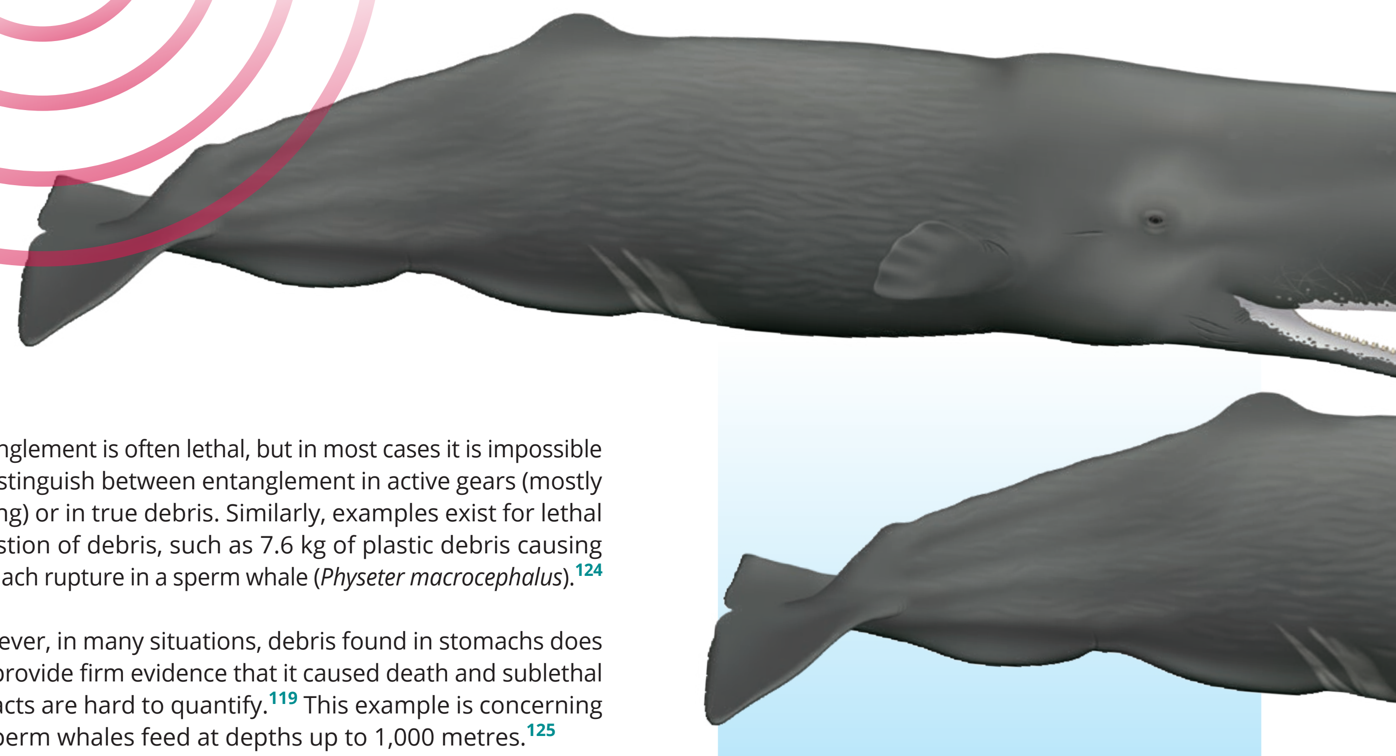
Many different substances to which marine mammals are exposed may adversely affect their health. These include natural elements that become more concentrated due to human activities, synthetic chemical compounds, oil-pollution-derived substances, marine debris, sewage-related pathogens, excessive nutrients causing environmental changes and radionuclides.[119] Although there is broad awareness of the threat of pollution to marine mammals, the long-term impact of pollution on marine mammal health is difficult to study and not well-known.[119]

Chemical pollutants include persistent organic pollutants, heavy metals, and pharmaceuticals and personal-care products.[120] Marine mammals are especially vulnerable to such pollutants because they often occur in polluted coastal waters, are long-lived and therefore accumulate pollutants over time, occupy high trophic levels and thus biomagnify pollutants, and cannot metabolically eliminate persistent chemicals.[121,122]

Marine anthropogenic debris, in particular synthetic materials, affects marine mammals. Individuals can die or be negatively impacted by entanglement in or the ingestion of plastic litter. Published records indicate that currently 66 per cent of marine mammal species have been affected – 41 per cent by entanglement and 50 per cent by ingestion[123] – but likely every species will eventually be affected.

© naturepl.com / Franco Banfi / WWF

UNAVOIDABLY, ALL MARINE MAMMALS WILL INGEST MICROPLASTICS, PARTLY BECAUSE MARINE MAMMALS' PREY SPECIES INGEST THEM AT SIGNIFICANT RATES.[129]



Sperm Whale illustration © Uko Gorter

Entanglement is often lethal, but in most cases it is impossible to distinguish between entanglement in active gears (mostly fishing) or in true debris. Similarly, examples exist for lethal ingestion of debris, such as 7.6 kg of plastic debris causing stomach rupture in a sperm whale (*Physeter macrocephalus*).[124]

However, in many situations, debris found in stomachs does not provide firm evidence that it caused death and sublethal impacts are hard to quantify.[119] This example is concerning as sperm whales feed at depths up to 1,000 metres.[125]

It is often unclear why marine mammals ingest debris. Contrary to what might be expected, ingestion of debris in the filter-feeding baleen whales (54 per cent) appears less common than in the more target-hunting toothed whales (62 per cent). Within species, the frequency of nonlethal ingestion of plastic debris is often poorly known, as sample sizes are usually small and research methods do not focus on detecting debris in stomach contents.[126] Nevertheless, ingestion rates of up to 35 per cent for individuals have been recorded for estuarine dolphins[127] and up to 12 per cent in harbour seals.[128] Unavoidably, all marine mammals will ingest microplastics, partly because marine mammals' prey species ingest them at significant rates.[129]

Microplastics have been found in the gut of humpback whales,[130] while their baleen can accumulate small plastic particles.[131] Negative physical and chemical impacts from microplastic ingestion have been shown experimentally to occur at lower trophic levels. Impacts in natural situations and at higher food web levels are not known, but may occur as some plastic additives have endocrine disrupting properties.[132] Effects of nanosized synthetic particles are even more unclear, but of concern as such particles may permeate cell membranes affecting cellular functions through physical or chemical interactions.[133]

Underwater noise pollution is of growing global concern because of its impacts on a wide range of marine species.[116,134] Whales in particular have evolved to use sound as their primary sense, and depending on the source, underwater noise can have a range of impacts on individuals and populations.[69]

Shipping is the leading contributor to ocean noise pollution worldwide[116] and in some parts of the ocean, underwater noise levels have doubled each decade since the 1960s.[115,116,135] Ship noise is characterized as continuous and generally low in frequency, although it can extend to high frequencies.[136] Most noise is incidentally caused by propeller cavitation (the formation and implosion of small bubbles against propellers as they rotate). Hull vibration and engine noise also contribute to a ship's acoustic footprint. Other sources of underwater noise range in frequency from low to high and can be high in their intensity. They include explosions, sonar, underwater construction and seismic survey.

UNDERWATER NOISE POLLUTION IS OF GROWING GLOBAL CONCERN BECAUSE OF ITS IMPACTS ON A WIDE RANGE OF MARINE SPECIES.[116,134]

Vessel noise has been shown to disrupt communication and feeding behaviour and cause displacement of whales from important habitats,[116] which can impact health and reproduction and lead to population declines. High-intensity sources of underwater noise can result in direct impacts through acute injury (temporary or permanent hearing damage) or death.[136–139]

© Henrik Lehnerer

Oil Rig in the Channel Island near Ventura California.

OIL AND GAS EXPLORATION AND EXTRACTION CAN DISTURB WHALES AND THEIR PREY THROUGH UNDERWATER NOISE POLLUTION, CONSTRUCTION OF SUPPORTING INFRASTRUCTURE, OIL LEAKS, ASSOCIATED SHIPPING AND THE POTENTIAL FOR LARGE, CATASTROPHIC OIL SPILLS.

OFFSHORE EXPLORATION AND COASTAL DEVELOPMENT

Industrial activities include land reclamation, the construction of infrastructure such as ports as well as facilities related to aquaculture, energy production and military activity. Potential impacts on whales include habitat loss, degradation or fragmentation, as well as, displacement or injury on account of construction and operational noise.[65]

Offshore oil and gas infrastructure such as pipelines and platforms have proliferated along continental margins and in the deeper oceans worldwide.[140] Oil and gas exploration and extraction can disturb whales and their prey through underwater noise pollution, construction of supporting infrastructure, oil leaks, associated shipping and the potential for large, catastrophic oil spills.

The ocean below 200 m depths is referred to as the deep-sea and is the largest biome on our planet, with much of its diverse life unmapped. Parts of the deep seabed also contain mineral deposits. Interest in deep seabed mining to extract minerals several kilometres below the surface is increasing. Until there is enough knowledge about the life and functions of the deep sea, diverse voices are calling for a moratorium on this emerging practice.[141] Seabed mining could affect whales and their prey through disturbance of the seafloor, sediment plumes, noise and pollution.[142]

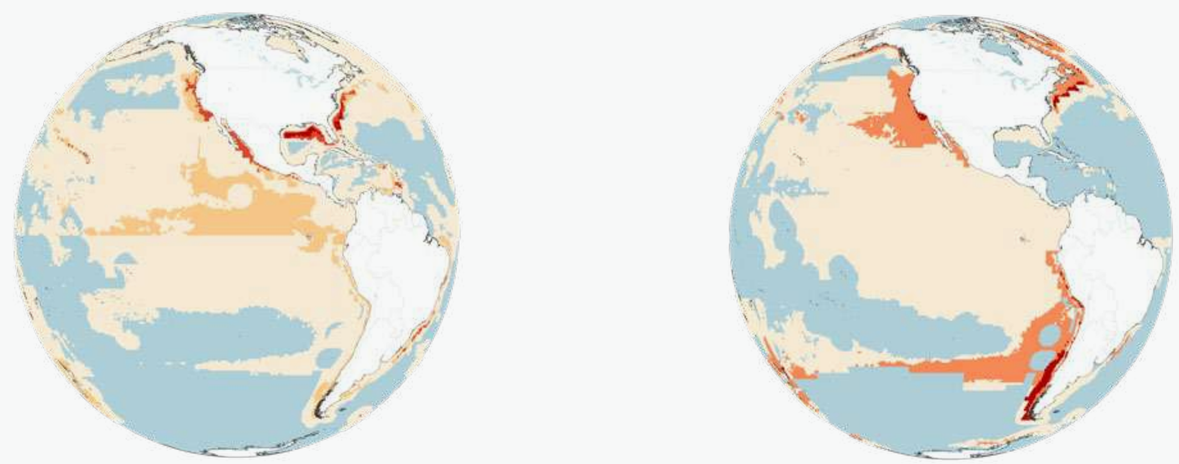
FIGURE 3

CUMULATIVE RISKS MAP FROM AVILIA ET AL (2018)[20]

This cumulative risk map shows the number of species affected by any threat based on the intersection of published documented threat categories (all threat types) and predicted species core habitat (AquaMaps presence probability threshold ≥0.6) – with a focus on the Eastern Pacific. Blue areas represent the core habitats for each group without any documented threat. Red areas represent high-risk areas or hotspots.

A.
CUMULATIVE RISK MAP FOR TOOTHED WHALES
(Toothed whales, N species = 65).

B.
CUMULATIVE RISK MAP FOR BALEEN WHALES
(Baleen whales, N species = 13).



Number of species in risk per cell (A): 1-4, 5-10, 11-15, 16-20

Number of species in risk per cell (B): 1-2, 3-4, 5-7

© naturePL / Mark Carwardine / WWF

CONSERVATION OPPORTUNITIES

Based on satellite tracking, photo identification and other data sources, we illustrate case studies of emerging blue corridors for whales, some hotspots where there is growing human interference and highlight conservation opportunities and ideas to implement solutions.

BERING STRAIT

The Bering Strait connects the Arctic Ocean to the Pacific Ocean. Each year it hosts immense seasonal migrations of more than one million marine predators, including bowhead, beluga and gray whales, seals and walrus. As well as being a key migratory corridor, it is a persistent hotspot for many marine species and is one of the world's most productive marine ecosystems.[50]

Seasonal migrations of Arctic and subarctic marine mammals closely follow the timing of sea ice retreat north in spring and its advance south in autumn. The highly productive, plankton-filled cold Arctic waters north of the Bering Strait also increasingly attract temperate cetacean species such as fin whales and killer whales from the Pacific Ocean up through the Strait and into the Arctic Ocean to exploit these rich feeding grounds in summer months. Gray whales travel more than 16,000 km each way annually to and from Mexico.[143,144] Humpback whales frequent the Bering Sea in summer and can be found as far north as the Chukchi and Beaufort Seas.[145] As well as their importance to the marine ecosystem, populations of whales that migrate through the Bering Strait are of immeasurable importance to coastal Indigenous Peoples in the United States and Russia, who have relied on them for millennia for their culture, nutrition and livelihoods.[143,146]

© naturepl.com / Martha Holmes / WWF

THE ARCTIC IS WARMING MORE THAN TWICE AS FAST AS THE REST OF THE PLANET DUE TO ANTHROPOGENIC CLIMATE CHANGE AND IS NOW WARMER THAN IT HAS BEEN AT ANY TIME DURING THE LAST 2,000 YEARS.

CONSERVATION CHALLENGES

A CHANGING ARCTIC

The Arctic is warming more than twice as fast as the rest of the planet due to anthropogenic climate change and is now warmer than it has been at any time during the last 2,000 years.[89,147] A major consequence of this is loss of sea ice. Summer ice extent has declined by 40 per cent since satellite observation began in 1979 and what remains is younger and thinner, melts earlier in spring and re-freezes later in autumn.[89]

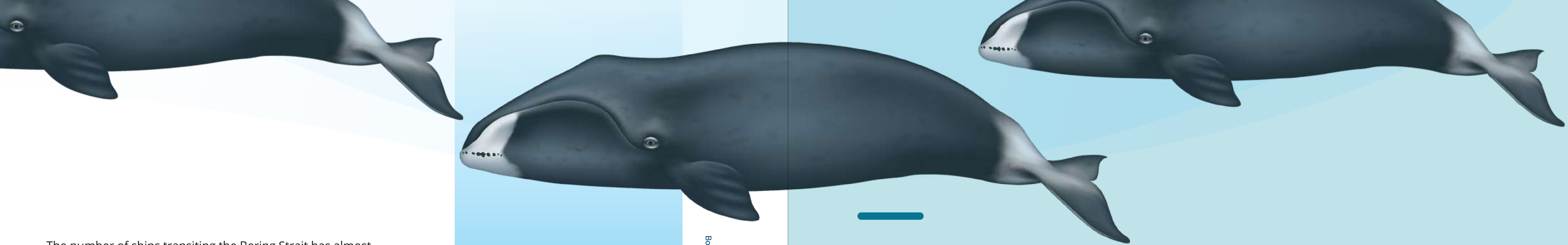
Sea ice has, until recently, been a physical barrier to heavy industrialization of the Arctic Ocean and associated impacts. However, as the ice-free season lengthens, this is rapidly changing. Financial experts estimate that future development in the Arctic will attract approximately a trillion dollars of new spending in the next 20 years.[148] Realisation of new development and infrastructure plans, stimulated by global demand for resources, is now possible due to the climate crisis. Extremely warm conditions in recent years have put the Pacific Arctic marine ecosystem under high pressure.[143] Whales in the Bering Strait region are contending with changes in prey availability, a higher risk of predation by killer whales and changes in sea ice and other climate drivers that cue migration and other life events.[143,149,150] Early signs of transformative change in the region include shifts in the productivity and distribution of fish species, changes in migrations of bowhead and beluga whales, and unusual mortality events for ringed, spotted and bearded seals and gray whales.[36,143,150–152]

GROWING RISKS FOR CETACEANS

On top of these dramatic ecosystem changes, multiple anthropogenic stressors are growing in the Bering Strait region. Projected increases in ship traffic and expanding commercial fisheries carry direct risks for cetaceans.

Known as the "fish basket" of the United States, the southeastern Bering Sea contains major fish stocks that make up a US$2 billion fishery[153] and account for about half the seafood landings in the country. As these fish stocks move northwards due to climate change, so too will commercial fishing pressure. In 2020, the Russian Federation announced plans to open the first commercial pollock fishery in the Chukchi Sea to take advantage of this species' apparent range expansion.[154] The Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean, known as the Central Arctic Ocean Fishery Agreement (CAOFA), that entered into force in 2021 indicates the interest that some fishing countries have in accessing potential fishery resources in the Central Arctic Ocean.

Shipping activity in the Bering Strait overlaps in space and time with whale migrations and brings several risks, including oil spills, ship strikes and underwater noise pollution.



Bowhead Whale illustration © Uko Gorter

The number of ships transiting the Bering Strait has almost doubled in the last decade. Where only 262 transits were recorded in 2009, in 2019, 494 ship transits were observed through the Strait, with large increases projected in the future.[155,156] Underwater noise pollution from current shipping – the amount of additional noise on top of the ambient underwater soundscape – is well above levels known to have a negative impact on whale communication.[157]

In addition to increases in shipping through the Bering Strait for local or national commerce, with the loss of sea ice, new global shipping routes through the Arctic are materializing to connect the world's oceans. Of four such routes, three would pass through the Bering Strait: the Northwest Passage, the Northeast Passage (which includes the Northern Sea Route) and the Transpolar Sea Route. All offer significant benefits of shorter distances compared to those through the Suez and Panama Canals.[89]

WITH TRANSFORMATION OF THIS MARINE ECOSYSTEM UNDERWAY, PROTECTION OF THESE MIGRATORY CORRIDORS TO MAINTAIN ECOLOGICAL CONNECTIVITY AND THE IMMENSE NATURAL VALUES OF THE REGION IS A MATTER OF URGENCY.[156]

CONSERVATION OPPORTUNITIES

INTERNATIONAL ACTION TO REGULATE SHIPPING NEEDED NOW

The Bering Strait is clearly an important migratory corridor and destination for marine wildlife and is vital for the many coastal Indigenous Peoples who use marine resources as a way of life. Climate change is also creating opportunities for commercial and industrial growth that will result in new and elevated risks for the Bering Strait marine ecosystem and its components, including endemic species like bowhead and beluga whales and seasonal visitors such as gray and humpback whales.

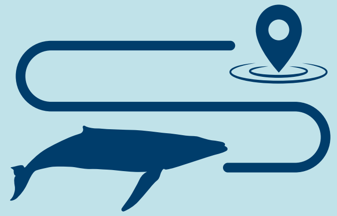
Commercial activities including shipping and fishing must be managed through national action and international cooperation, especially between the Russian Federation and the USA, as the Bering Strait is within the territorial waters of both countries.

Development of a holistic system to manage shipping, thereby improving maritime safety and environmental protection, could include the use of emerging e-navigation technologies to enable real-time monitoring and information exchange; development of seasonal or dynamic MPAs; adoption of voluntary or mandatory speed restrictions and standards of care and operation led and implemented by the maritime industry.[117,156]

WWF is working with governments, local communities, and other conservation organizations in Russia and the United States to identify area-based protections in the Bering Strait to protect whales and other marine mammals, and the communities that rely on these areas. Areas to Be Avoided (ATBAs) are special areas identified by the IMO to keep large vessels away from sensitive habitats. WWF has identified the Diomede Islands as important areas that require further protection and recommends implementing ATBAs around both islands.

The CAOFA, recently entered into force, creates the opportunity to establish best practices for a science plan, standards for exploratory fisheries, and development of a regional fishery management organization (RFMO) for the Central Arctic Ocean. If implemented consistent with the Precautionary Approach and utilizing Ecosystem Based Management principles, the CAOFA can ensure the sustainability of Arctic fisheries and minimize the potential impact of commercial fishing on the Bering Strait. With transformation of this marine ecosystem underway, protection of these migratory corridors to maintain ecological connectivity and the immense natural values of the region is a matter of urgency.[156]

HOW DO WE KNOW WHERE WHALES MIGRATE?



SATELLITE TRACKING

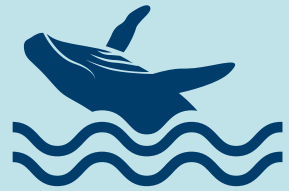
For several decades, scientists have used satellite tracking – also known as satellite telemetry – to better understand the movement patterns and large-scale behaviour of marine mammals. Satellite tags have been developed to track marine mammals for several months at a time, collecting spatial information using orbiting satellite networks. Similar to a GPS, satellite tags send and receive signals to and from satellites several times per day and these are used to calculate the position of the tagged animal. Data are sent via satellite to users and offers a remote means for monitoring animals that otherwise would be nearly impossible to track. Over time, positions from satellite tags can be used to determine the behaviour of the tagged animal (for example, migrating or transiting versus foraging) by using mathematical models. Because satellite tags can collect data over long periods, they are a useful tool for understanding fundamental aspects of the life history of marine mammals, including when and where they migrate, how much time they spend in migratory corridors and where these corridors may overlap with human activities.

To study whale migration, satellite tags are generally deployed on animals on their breeding or feeding grounds while animals are close to shore and are remaining in more or less the same area. As animals transition to migratory behaviour, satellite tags provide critical information on when migration occurs, the routes that animals take during migration, and when they reach their destination. Continuously tracking migrating animals is nearly impossible to do from a logistical point of view without the aid of satellite transmitters. By using satellite tag technology, scientists can learn, for example, about the routes that marine mammals take, the speed at which they move and whether different portions of the population migrate at different times. The latest satellite tags can also record dive behavior, including feeding events, adding an additional dimension to the data they can collect.[158] Additionally, satellite tag data can be used to show when migrating marine mammals overlap in space and time with human activities such as fishing and shipping, and to determine the amount of time that animals spend in the territorial waters and exclusive economic zones (EEZs) of different countries.

PHOTO-IDENTIFICATION

One of the most commonly used methods for tracking the movements of marine mammals is photo-identification. Most animals have markings that are unique to individuals and in the case of humpback whales, the patterns of scarring and pigmentation on the underside of the tail flukes can be used to identify individuals with great precision. Photographing animals is a relatively simple and passive way to collect valuable information on the presence of an animal in a certain place at a certain time. By collecting fluke (or other body part) images regularly in the same place, researchers can learn about occurrence patterns of individuals over long periods of time or within a season. However, some of the most critical information on animal movements comes from when researchers compare photographic images across regions to make matches. In this case, many of the main migratory end points (feeding and breeding grounds) for marine mammal populations have been identified and fidelity to these has been established for many individuals. Researchers are leveraging artificial intelligence technology to greatly facilitate and expedite the arduous matching process, for example via platforms like ***Flukebook.org***.[159]

Photo-identification is likely the most ubiquitous marine mammal data collected around the world and enables researchers to define migratory destinations for populations and the patterns of occurrence of individuals in these areas over time. As well, photo-identification can help determine the frequency of reproduction in individuals and can provide information on entanglements and other scars/injuries incurred from incidents with human activities.



INDIGENOUS KNOWLEDGE

Vast knowledge about whales, their movements, behaviour and ecology is held by coastal Indigenous peoples around the world, particularly those who have relied and still rely on whales for their culture, food and livelihoods. Indigenous Knowledge, or Traditional Ecological Knowledge, is accumulated by people who have successfully lived in close connection with nature for generations, often in remote places, and often as the only year-round residents, enabling deep, detailed and experiential observations and knowledge to be gained.

Indigenous Peoples' knowledge is increasingly recognized by scientists as unique and intrinsic to understanding the nature of biodiversity and ecosystems. Indigenous Knowledge has been used alone and alongside scientific research to understand whale migrations, including pathways, timing, changes and factors influencing its onset (e.g. for beluga and bowhead whales).[160,161]

© Tyler Gray

Humpback Whale Hawaii

HAWAII TO SOUTHEAST ALASKA

The importance of the Hawaiian Islands as a breeding area for North Pacific humpback whales is underscored by the fact that it is used during winter months by almost half (about 10,000 animals) of the population inhabiting the North Pacific.[162]

These whales come from various high-latitude feeding areas across the North Pacific, but the vast majority originate in southeast Alaska and adjacent feeding areas in northern British Columbia and the northern Gulf of Alaska.[162] Humpbacks are abundant in Hawaii from mid-December through early April, reaching peak numbers in February and March, when most females are believed to go into estrus.[163] The pattern of male activity around females suggests that the peak in ovulation for non-pregnant females is from December to early February, while a secondary peak from mid-February to March appears to be the result of pregnant females from the previous winter going into estrus after giving birth. Mating occurs during the brief period (a few days) when females are receptive, so most individuals (certainly most females) may be present in Hawaii for only a few weeks.[163]

Thus, we might expect that a typical adult female that has spent spring, summer and part of the autumn in the feeding areas may migrate to Hawaii (a distance of ~4,000–5,000km) in late autumn (say, late November), arrive there 30 to 40 days later (late December), remain in Hawaii for 20 to 30 days (40 days if rearing a calf) while looking for a mate, and then undertake the return migration to finally arrive in the feeding area at the beginning of spring (mid-March) of the following year. The pattern of male residence in Hawaii is possibly similar, although the most dominant ones may spend significantly longer (up to 91 days).[163]

A recent comprehensive analysis of the movements of 86 satellite tagged animals in Hawaii from 1995 to 2019 showed that while in the Hawaii breeding area, whales moved at a mean speed of 1.62 km/h and that their residency ranged from 1.1 to 42.8 days, with a mean of 13.1 days.[164] Once they started their migration to the feeding areas, tagged whales moved at a mean speed of 4.65 km/h and their migration lasted between 28 and 44.8 days, with a mean of 34.2 days.[164] However, migration speed was not sustained but showed variation over time, with periods of increased and decreased speed lasting several days.[164]

THE MIGRATION TO AND FROM THE FEEDING AREAS TAKES THE WHALES ACROSS A VAST EXPANSE OF THE OPEN OCEAN THAT IS REGULARLY CROSSED BY MAJOR SHIPPING “HIGHWAYS” WHERE THE RISK OF SHIP STRIKE IS ELEVATED.

CONSERVATION CHALLENGES

By virtue of Hawaii’s location in the middle of the North Pacific, the migration to and from the feeding areas takes the whales across a vast expanse of the open ocean that is regularly crossed by major shipping “highways” where the risk of ship strike is elevated.[165] Patterns of ocean currents in this region lead to the formation of convergence zones, most famously the Great Pacific Garbage Patch, where abandoned, lost or discarded fishing gear tends to accumulate,[108,111,166,167] increasing the risk of entanglement. At least 46 per cent of the Great Pacific Garbage Patch is made of discarded fishing gear.[111]

While the Hawaiian humpback whale population has been recovering strongly,[168] recent climate-related perturbations to the North Pacific ecosystem known as “marine heatwaves” appear to have affected survival and recruitment in this population.[169–172]

CONSERVATION OPPORTUNITIES

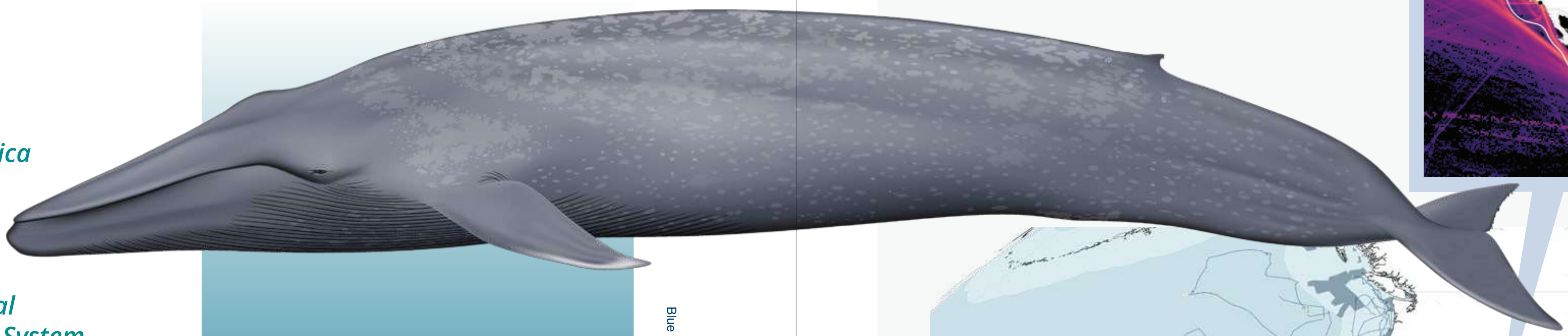
Preventing fishing gear loss is the top priority, with education, voluntary measures and regulations all having a role to play. Prevention measures include restricting the use of high-risk gear in certain areas or times of year, marking fishing gear so it’s clearly visible and the owner can be identified, and improving end-of-life disposal and recycling.

Even so, some fishing gear will inevitably get lost, so it’s important to adopt mitigation measures. Including biodegradable components so the gear breaks down quickly is one effective way to prevent ghost fishing. Finally, since plastic gear can have long-lasting impacts, it’s important to remove and retrieve as much lost and abandoned gear as possible, though this can be expensive, particularly in deep-sea habitats. Programmes for reporting and retrieving lost gear already operate in some places, and “fish for litter” schemes – which reward fishers for bringing back marine debris, including ghost gear – are growing in popularity.[107] WWF is urging governments to sign on to the Global Ghost Gear Initiative (GGGI) and implement its fishing gear best management practices to prevent gear loss. The GGGI is the world’s only global cross-sectoral alliance of 100 organizations, including WWF. By joining the GGGI, countries will access critical technical support to address ghost gear in their national fisheries, contribute to the collective impact of GGGI and its members, and help to develop the global capacity to solve this problem throughout our ocean.[107]

Globally, a legally binding UN agreement is needed as a priority to stop the leakage of plastics into our oceans by 2030 and accelerate the transition to a circular economy for plastic so it never becomes waste or pollution.[173]

WESTERN COAST OF NORTH AMERICA

The coastal waters of North America are important migratory routes and foraging areas for species including gray, blue, humpback and fin whales. Blue whales move between the Eastern Tropical Pacific and the California Current System or Gulf of Alaska, but probably feed year-round, targeting ephemeral, dynamic concentrations of krill.



Blue Whale illustration © Uko Gorter

Blue whales in the Eastern North Pacific are listed as Endangered under the *United States Endangered Species Act*, NOM-059 of Mexico, the Species at Risk in Canada and Protected under the *United States Marine Mammal Protection Act*. Their population size in this region is about 1,500 animals.[174] They migrate between the California Current region or the Gulf of Alaska and the Eastern Tropical Pacific, likely tracking abundant krill that they feed on year-round.[3,175–177]

CONSERVATION CHALLENGES

Off the United States West Coast, migratory routes and foraging areas of many species overlap with various kinds of ship traffic,[178–183] including commercial traffic to and from the ports of Los Angeles and Long Beach, two of the world's 50 busiest container ports. The risk of collisions between ships and whales is thus high in this area: it is estimated that most mortality risk for blue, humpback and fin whales is concentrated in about 10 per cent of the United States West Coast EEZ.[183] Fatal collisions with ships are a leading source of mortality for blue, fin, humpback and gray whales,[184] and may be one of the factors inhibiting recovery of blue whale populations post-whaling.[183,185,186] Studies of the impacts of acoustic disturbance on blue whales has shown that these whales generally are affected disproportionately when feeding and as a result of disturbance, stop feeding.[187] Animals that are chronically exposed to disturbances, therefore, are at risk of losing critical foraging opportunities that can lead to changes in body condition that ultimately may lead to changes in reproductive rates and decreased population growth.[188,189]

FATAL COLLISIONS WITH SHIPS ARE A LEADING SOURCE OF MORTALITY FOR BLUE, FIN, HUMPBACK AND GRAY WHALES,[184] AND MAY BE ONE OF THE FACTORS INHIBITING RECOVERY OF BLUE WHALE POPULATIONS POST-WHALING.

FIGURE 4

EASTERN NORTH PACIFIC BLUE WHALES

Over 17 years between 1994 and 2017, 189 whales were satellite-tracked for 2-504 days. Locations were recorded in the EEZs of nine countries with 15 per cent of locations recorded in the high seas. Most locations were in United States (52 per cent) and Mexican (32 per cent) waters. The satellite tracks cover an area of 23 million km². In this area, the mean shipping density (number of vessels counted in 2015) is 0.36 vessels/km², but in the whales' core-use area, it is 0.99 vessels/km².

FIGURE 5

GRAY WHALE SUMMER FEEDING AND WINTERING AREA

Satellite tagging shows the yearly round-trip migration of gray whales between the Arctic and Mexico along the west coasts of Canada and the United States.

LEGEND

Wintering Lagoons[1]

Whale Location[2,3,4,5]

Satellite-tagged Whale Route[6,7]

GRAY WHALE SUMMER HABITAT[5,8,9,10]

Regular Use

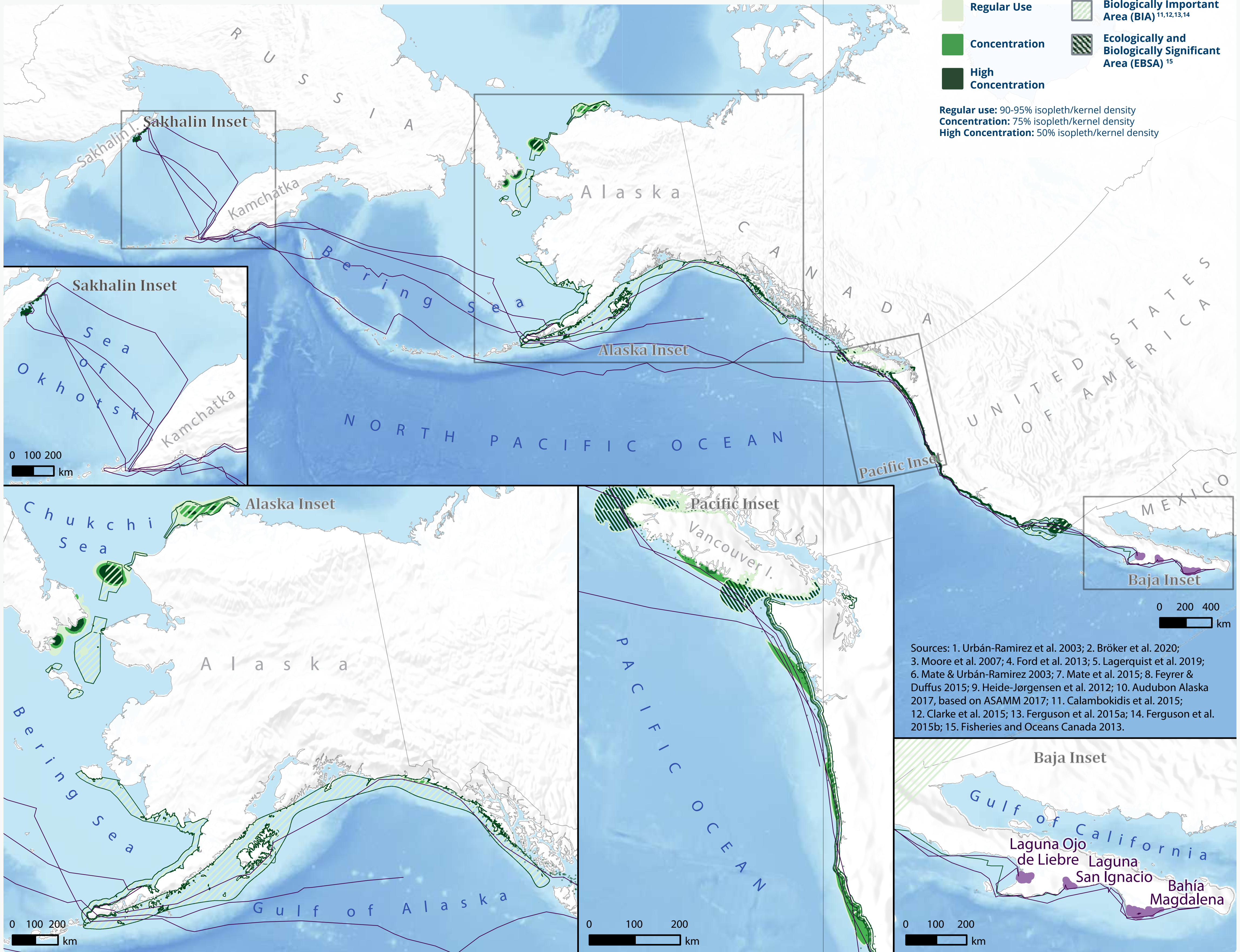
Concentration

High Concentration

Biologically Important Area (BIA)[11,12,13,14]

Ecologically and Biologically Significant Area (EBSA)[15]

Regular use: 90-95% isopleth/kernel density
Concentration: 75% isopleth/kernel density
High Concentration: 50% isopleth/kernel density



Sources: 1. Urbán-Ramirez et al. 2003; 2. Bröker et al. 2020; 3. Moore et al. 2007; 4. Ford et al. 2013; 5. Lagerquist et al. 2019; 6. Mate & Urbán-Ramirez 2003; 7. Mate et al. 2015; 8. Feyrer & Duffus 2015; 9. Heide-Jørgensen et al. 2012; 10. Audubon Alaska 2017, based on ASAMM 2017; 11. Calambokidis et al. 2015; 12. Clarke et al. 2015; 13. Ferguson et al. 2015a; 14. Ferguson et al. 2015b; 15. Fisheries and Oceans Canada 2013.

© Barbie Halaska / The Marine Mammal Center
A gray whale found dead off Point Reyes National Seashore in Northern California

CONSERVATION CONCERN: CUMULATIVE IMPACTS ON GRAY WHALES ALONG THEIR SUPERHIGHWAY FROM THE ARCTIC TO MEXICO

Since 1 January 2019, elevated gray whale strandings have occurred along the West Coast of North America from Mexico to Alaska. An unusual mortality event was declared by the National Oceanic and Atmospheric Administration (NOAA) in May 2019, and through May 2021 at least 454 strandings were reported, including 218 in Mexico, 218 in the United States and 18 in Canada.[190]

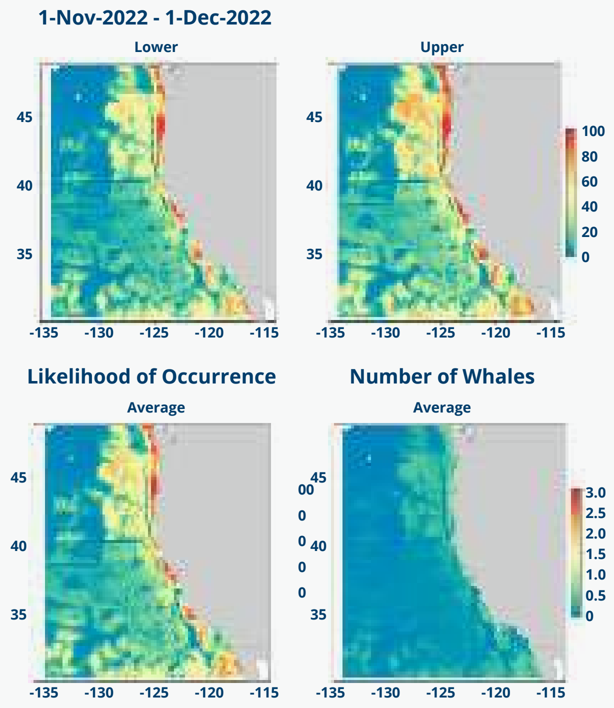
The peak of the unusual mortality event was in 2019, and the number of strandings has been decreasing in 2020 and 2021. Most of these strandings have occurred from April through June, coinciding with the northbound migration from the breeding to the feeding areas, when the nutritional status of the whales is normally at its lowest. However, as the primary source of mortality appears to be severe malnutrition, it is likely that the deaths are related to a lack of food during the feeding season in the Arctic.[191] As a result of climate change, dramatic environmental changes took place in the North Pacific and the Arctic through the 2010s that likely affected the annual primary production cycles and the marine food chain, leading to the whales not finding sufficient food.[143]

The net result has been a loss of about 24 per cent of the eastern gray whale population from the 2016 estimate of around 27,000 whales.[190,192] During this time, the whales also appear to be arriving later by about a month to the breeding lagoons of Mexico in winter, although the departure dates have remained constant, suggesting that they are spending less time in the lagoons.[193] Health assessments have indicated an increasing number of whales in poor body condition, to more than 30 per cent of the animals in the breeding lagoons in recent years.[193] Gray whales feed on a diet of invertebrates but are otherwise opportunistic feeders and can use multiple strategies, including suction feeding, lunge feeding and skim feeding that allows them to exploit alternate prey. This flexible foraging strategy confers the species resilience against these short-term environmental fluctuations, which likely allowed the gray whale population to rebound to greater numbers than before after a similar unusual mortality event in 1999–2000, during which the population was reduced by 23 per cent.[192]

FIGURE 6

MODEL ESTIMATES FOR BLUE WHALES OFF THE US WEST COAST FOR JULY 2021

For more information about WhaleWatch visit ***fisheries.noaa.gov/west-coast/marine-mammal-protection/whalewatch***



CONSERVATION OPPORTUNITIES

NEW TECHNOLOGY TO PROTECT WHALES FROM SHIPPING AND FISHING IMPACTS

To help reduce human impacts on whales, a collaborative initiative between NOAA, academic scientists and shipping companies developed WhaleWatch, a computer-based tool that provides predictions of where blue whales are likely to be off the United States West Coast.

The tool uses models that link whale tracking data to environmental conditions to predict the likelihood of whale presence.[180] This near real-time information helps reduce human effects on whales by providing information on where the whales occur and hence where whales may be most at risk from threats such as vessel strikes, entanglements and underwater noise.

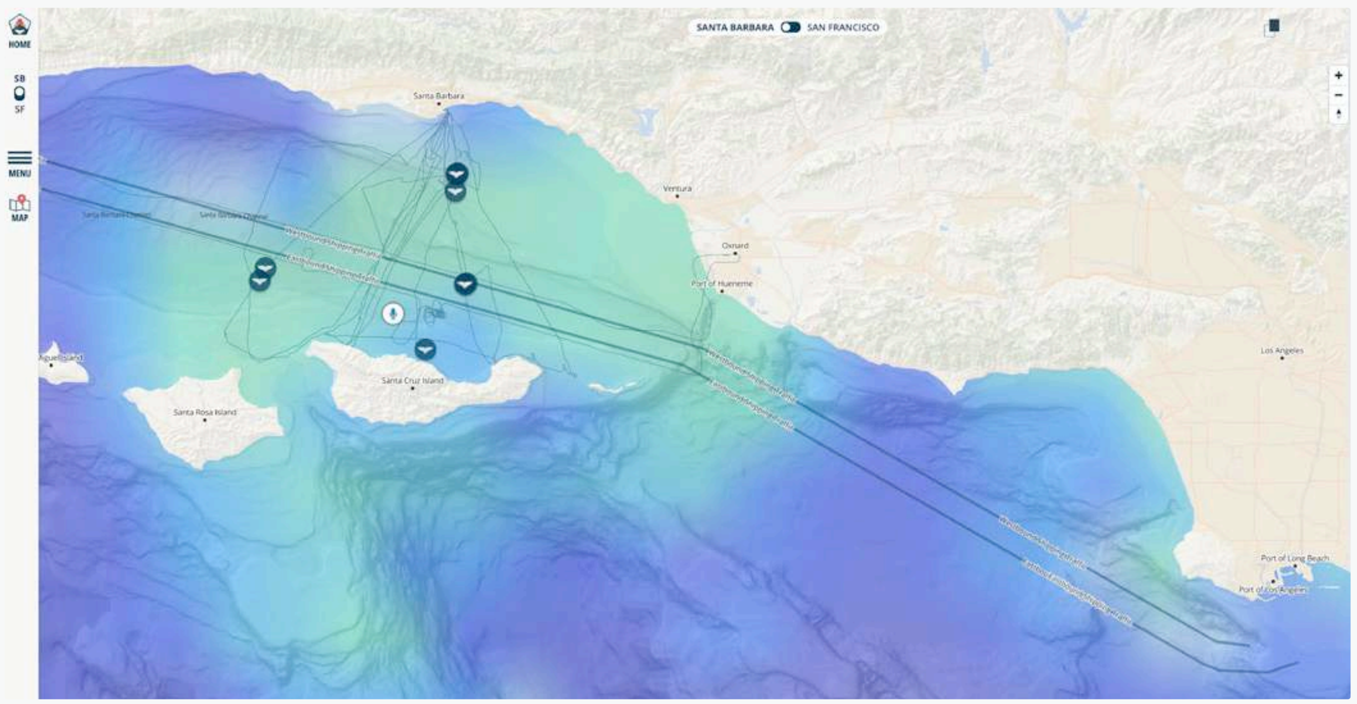
For more information, see:

COASTWATCH.PFEG.NOAA.GOV/PROJECTS/WHALEWATCH2/

Another recent, related effort is Whale Safe, a technology-based mapping and analysis tool developed by the Benioff Ocean Initiative and partners. The tool collects and displays near real-time whale and ship data for the Santa Barbara Channel, with the goal of helping to prevent fatal ship collisions with whales.[178,179,194]

FIGURE 7 **WHALE SAFE PLATFORM**

For more information, see ***whalesafe.com***



In 2022, the tool was expanded to provide coverage for the busy shipping channels outside of San Francisco Bay. 2018 and 2019 were the worst years on record for whale-ship collisions off the West Coast of the United States. Despite this trend, there are solutions to combat the problem. Research demonstrates ships that slow to 10 knots in areas with high whale presence significantly reduce the danger to whales in the area.

For more information, see:

WHALESAFE.COM

REDUCING VERTICAL LINES IN THE WATER TO ELIMINATE ENTANGLEMENT

Large whale entanglements on the West Coast of the U.S. have increased dramatically in recent years.[195,196] In California, from 2014 through 2017, at least 142 whales—mainly humpbacks—became entangled in crab pot ropes. Several more were reported for 2018.[197]

Currently, fishermen use rope to connect surface buoys to fixed gear on the seafloor, which allows them to mark the location of and retrieve deployed gear. On-demand, or ropeless, fishing removes these static vertical buoy lines from the water column while allowing fishermen to continue to fish their current gear, reduce entanglements and minimize gear loss.[195,198]

The technologies – marking and retrieving traps without buoys or end lines – are currently being explored and tested in both Canada and the US.[199,200] The development and operational use of ropeless fishing has the promise to eliminate most fixed gear entanglements as well as allow access to closed fishing grounds.[201] Ropeless technologies represent a more fundamental change for fishers. There is further development and testing needed to ensure that these technologies provide a safe, legal, practical and affordable alternative to scale up its use and impact in a changing climate.[200]

Existing whale-safe technologies include weak ropes or weak breaking points (e.g. sleeves and cutters), which is based on evidence that ropes with breaking strengths of 1,700lbs could reduce the number of life-threatening entanglements by allowing whales to swim free more easily.[202] The National Marine Fisheries Service requires all trap/pot gear to use weak links at the buoy line since the early 2000s. In Canada, weak rope will be mandatory by the end of 2022 followed by maximum rope diameters, sinking rope and reductions in vertical and floating rope[200] whereas the US has mandated sinking groundlines since 2007.[203]

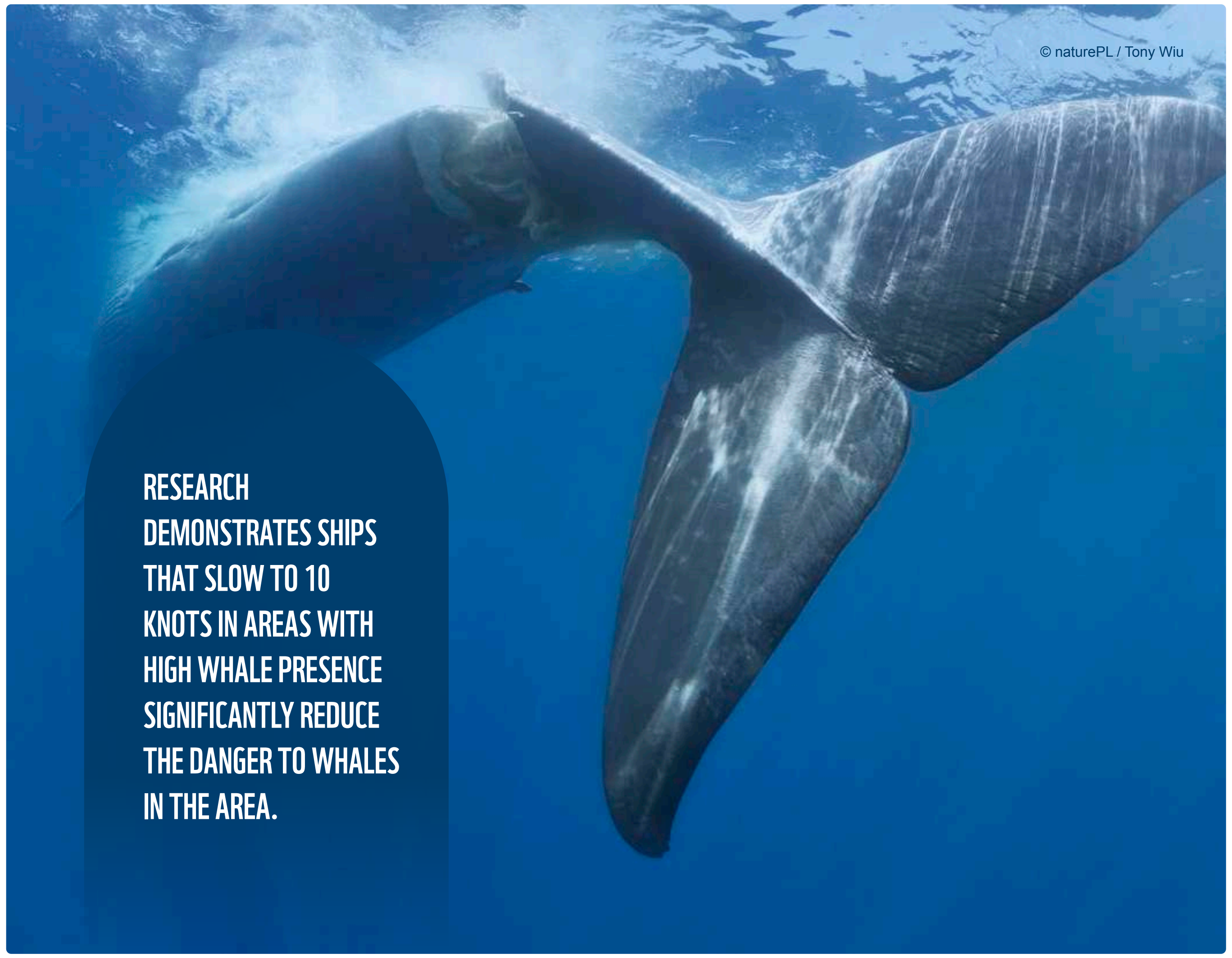
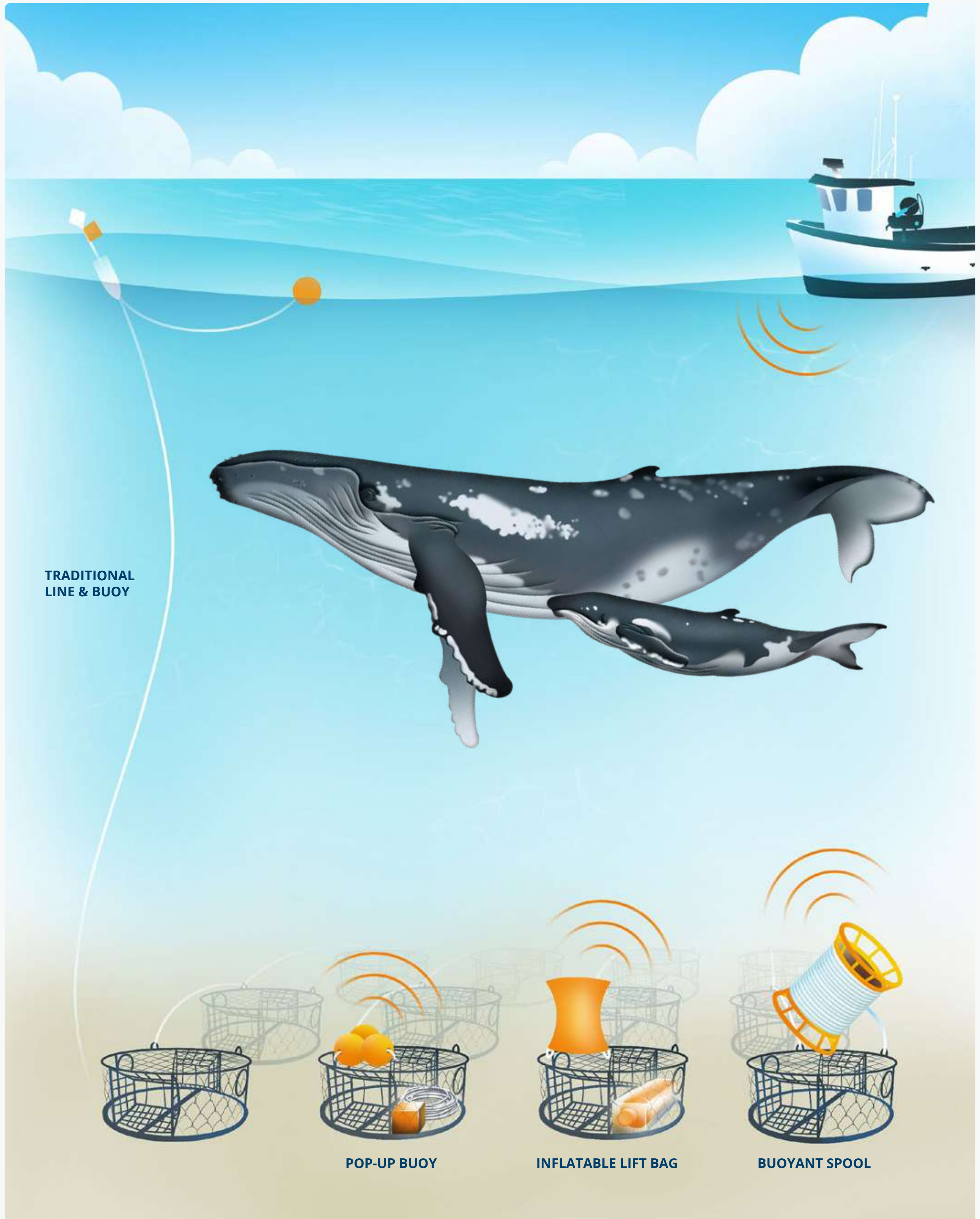


FIGURE 8

AN ILLUSTRATION OF ON-DEMAND, OR ROPELESS, FISHING TYPES.[204]



© Karel Beets ECOBAC

A humpback whale entangled in fishing nets. A team from Mexico's National Whale Disentanglement Network, known as RABEN, attempts to free the whale from the net.

NETWORK OF MPAS AND CONNECTIVITY

In 1972, Mexico was the first country in the world to create a whale sanctuary in the Laguna Ojo de Liebre, a coastal lagoon in the Pacific coast of the Baja California Peninsula. This area is home of the most important gray whale breeding grounds.[56] Since then, a network of MPAs has been established, which now covers 22.05% of Mexico's marine territory.

In particular, the protected areas in the Mexican Pacific hold globally significant reproduction areas for migratory gray whales (the El Vizcaino Biosphere on deReserve),[205] humpback whales (National Parks of Revillagigedo, Cabo Pulmo, Islas Marietas and Huatulco)[206,207] and blue whales (Loreto National Park)[208] as well as other key habitats along their migratory routes (the Islas del Pacifico de la Península de Baja California, Islas Marias Biosphere Reserves and the Islas del Golfo de California Protection Area for Flora and Fauna).[209–211]

All cetaceans that occur in Mexico are protected by national legislation. Mexico's protected areas play a significant role managing critical habitats of migratory whales in North America, but need to be strengthened.[212] The development of environmental policies specifically designed to strengthen the conservation of whales, have contributed to strengthen the protection of migratory whales outside protected areas, increasing connectivity and community participation.[213] An official standard has been put in place to regulate all whale-watching activities, and response protocols for whale strandings and entanglements have been developed.[214–216]

At least 10 stranding networks work under the auspices of the Federal Attorney for Environmental Protection along the Mexican coasts. Such networks integrate staff from government agencies, research facilities and non-government organizations, and have assisted hundreds of strandings since 2014, but heavily rely on volunteers and lack government funding.[217] The National Whale Disentanglement Network, known as RABEN, integrates 15 trained teams of disentanglement experts with 180 volunteers along the Mexican Pacific Coast, all equipped with specialized gear to assist in the rescue of entangled whales. The network has been able to confirm 239 entanglements of six whale species, with humpbacks being the most affected (86 per cent). During the 2021–2022 season, the network received 37 entanglement reports (31 confirmed and 6 unconfirmed) and was able to successfully rescue 7 whales (six humpbacks and one gray). This network relies on philanthropic funding.


© naturepl.com / Doug Perrine / WWF

ENTANGLEMENT AND MORTALITY IN FISHING GEAR, SHIP STRIKES AND CLIMATE CHANGE ARE THE MAIN THREATS TO WHALES IN THE EASTERN PACIFIC.

ADDRESSING THESE PROBLEMS REQUIRES INFORMATION ON ECOLOGY, DEMOGRAPHY AND THE IDENTIFICATION OF CRITICAL HABITAT AND MIGRATION ROUTES.

EASTERN TROPICAL AND TEMPERATE PACIFIC

The Eastern Tropical and temperate Pacific encompasses territorial waters, EEZs and island territories of 14 countries, as well as an extensive marine area beyond national jurisdictions between Mexico and Chile. The combination of ecosystem diversity and high productivity has fostered a high diversity of cetacean species in this vast region. More than 40 species of cetaceans inhabit the eastern Pacific, including nine baleen whales (Mysticeti) and more than 30 species of toothed cetaceans (Odontoceti).[218]

Understanding the large-scale distribution patterns of these species is critical to promoting their conservation. Because the breeding grounds of most migratory whales are in the tropics and subtropics, populations of the same species in both hemispheres may share the same breeding grounds in the eastern tropical/subtropical Pacific, but at different times of the year. This is the case of the humpback whale on the coasts of Central and South America and probably also with blue whales in the Galápagos Islands and the Costa Rica Dome.[8,219–221] The Costa Rica Dome is a regional centre of high productivity and likely supports high prey availability for cetaceans within the Dome and in surrounding waters. The productive equatorial waters of the Galápagos Islands also contain important regional habitats[222] and have been subject to recent high intensity industrial fishing along its EEZ.[223]

Sperm whales (*Physeter macrocephalus*) are a cosmopolitan species. Females and young males are found in tropical and subtropical waters. They are deep-diving predators with a broad diet of squid.[224] Other large whale species such as Bryde's whales also have wide ranges of distribution in the region, without an evident periodic migration.[225] Even so, both can show large-scale movements depending on the availability of food or specific oceanographic conditions.[226–228]

In this region, humpback whales breed in warm coastal waters from northern Peru north to Nicaragua mainly from July to October.[229] Satellite tracking studies of these whales have followed their long migrations along the Central and South America coast to the Antarctic Peninsula,[227,228,230] where they feed on krill in the Antarctic summer. Among whales tagged off Ecuador, mothers and their calves seemed to prefer the longer, coastal route to Antarctica, while lone adults seemed to prefer a more direct offshore route, sometimes hundreds of kilometres from the coast.[227] More recent tracking has revealed two areas where migrating whales converge near the southernmost point of Chile as well as Peru's Illescas Peninsula, where they could be exposed to increased human activities.[230]

While migrating, eastern South Pacific humpback whales spent 64 to 79 per cent of their time inside the jurisdictional waters of these countries, and 21 to 36 per cent of their time in international waters.[230]

The coastal marine ecosystems of Chile are among the most productive in the world. This is particularly the case for the Chiloense Marine Ecoregion, a well-known coastal region of northern Patagonia with high biological productivity, great ecological value and the presence of emblematic species in serious states of conservation. Hundreds of blue whales and humpback whales migrate to the Chiloense Marine Ecoregion to feed and nurse their young every year, where the Corcovado Gulf, the Chiloé Archipelago's inner sea and Moraleda Channel are some of the most important feeding grounds in all of Patagonia.[231,232]

The Corcovado Gulf is currently considered the largest feeding ground for blue whales in the southern hemisphere, where other baleen whales such as the humpback whale, sei whale and fin whale are frequently observed feeding or migrating. It is also possible to observe different species of toothed whales such as sperm whales, Peale's dolphins (*Lagenorhynchus australis*) and killer whales (*Orcinus orca*), among others.

CONSERVATION CHALLENGES

Entanglement and mortality in fishing gear, ship strikes and climate change are the main threats to whales in the eastern Pacific. Addressing these problems requires information on ecology, demography and the identification of critical habitat and migration routes. However, data availability is a weakness for this region that cannot be overcome in the short term. Therefore, proactive conservation strategies are required in the face of this knowledge gap. Whales' broad distributions, the inherent difficulties in studying highly mobile animals at sea, and the different threats they face are major challenges for their conservation.

The IWC has identified the Gulf of Panama as a High Risk Area where humpback whales are at high risk of ship strike.[233,234] In December 2014, the IMO adopted a Traffic Separation Scheme with corresponding inshore traffic zones and seasonal speed limits of less than 10 knots to reduce the whale-vessel strike risk in this area. Humpback whales are present in the area from July to September.[221,235,236]

Recent analysis shows that compliance varied depending on vessel type using the Traffic Separation Scheme and overall speed compliance was low.[237] In Ecuador, both ship strikes and entanglements in fishing nets have been reported.[238,239]

Along the coast of Peru, whale-watching has increased exponentially in the last 5 to 10 years and there is no formal regulation that protects whales. A recent study recommended that whale-watching regulations be implemented to regulate the number of boats, the distance to the whales, boat speed, duration of observation, and that encounters with calves should be limited. Poor whale-watching practice can elicit short-term behavioural responses besides negative impacts from noise emitted by vessels.[240]

Studies of movements and dive behaviour have shown that blue whales within fjords in the northern Chilean Patagonia are at high risk of ship strike in specific areas and at specific times.[241,242] Areas of high risk of ship strike have also been identified in the southernmost part of Chile.[243] In the central-south coast of Chile, two fin whales were found stranded in 2018 and 2019 with signs of ship strike.[244]

High density of marine ship traffic occurs between Chiloé Island's inner waters and the Pacific Ocean as well as the channel and fjords from southern Chile through the Magellan Strait, a narrow passage connecting the Pacific and Atlantic oceans in South America. Between [249] and 1,322 vessels navigate this area, with sizes varying between 10 to 200 m long. Vessel speed ranges between 8.3 and 22.5 knots, and recent studies have identified around 729 active vessels operating per day in association with the aquaculture industry in this region.[241]

MAPS OF IUCN IMPORTANT MARINE MAMMAL AREAS AND MARINE PROTECTED AREAS

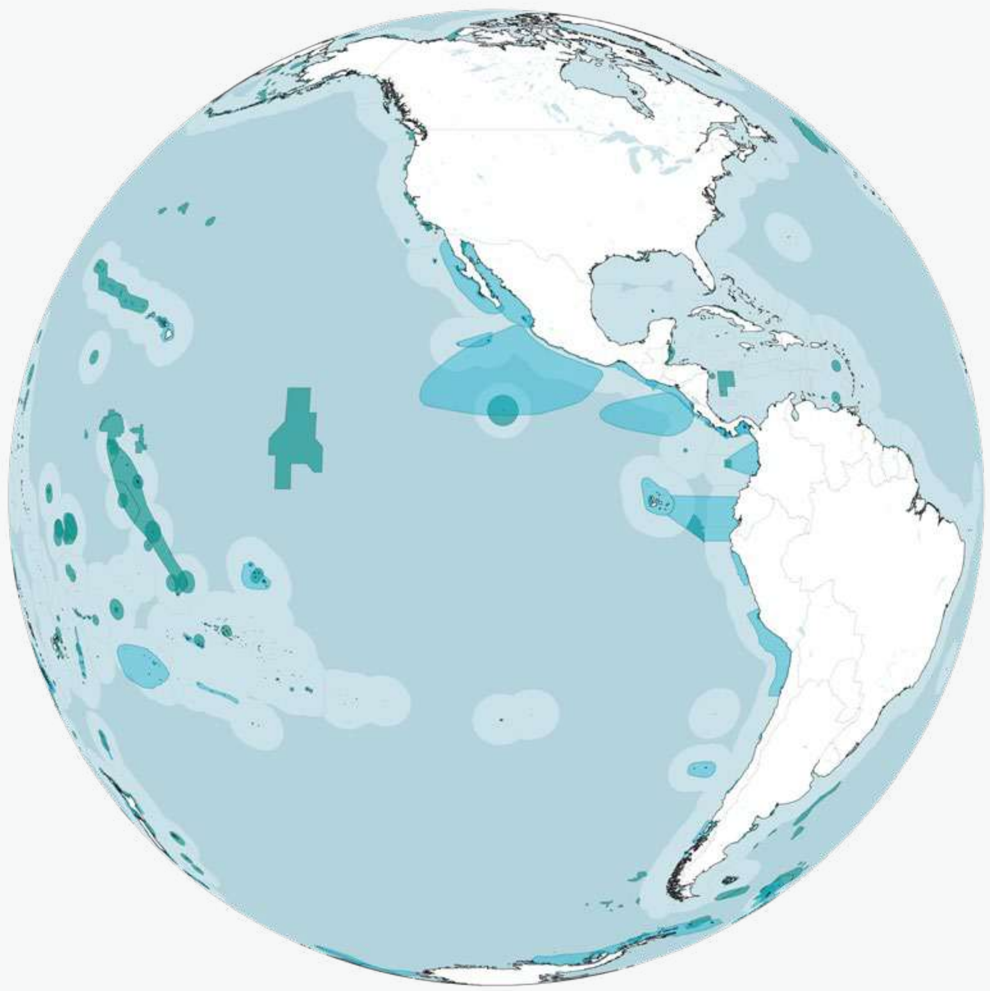
Important Marine Mammal Areas (IMMAs) are a tool developed by the Marine Mammal Protected Areas Task Force of the IUCN Species Survival Commission and World Commission on Protected Areas.[392,393]

IMMAs highlight areas that are important for one or more marine mammal species and have the potential to be managed for conservation. In this context, "important" means "any perceivable value, which extends to the marine mammals within the IMMA, to improve the conservation status of those species or populations". IMMAs thus provide an objective and consistent framework to identify the most critical marine mammal habitats worldwide, to prioritize their conservation and inform the designation and management of networks of MPAs.[263]

In June 2022, a week-long workshop with the region's leading scientists compiled data on candidate areas for peer review. As a result of this process, in November 2022 the Task Force updated its e-Atlas with 36 new IMMAs, 5 candidate IMMAs, and 11 Areas of Interest for the South East Tropical and Temperate Pacific Ocean—a region spanning from northern Mexico to the southern tip of Chile.

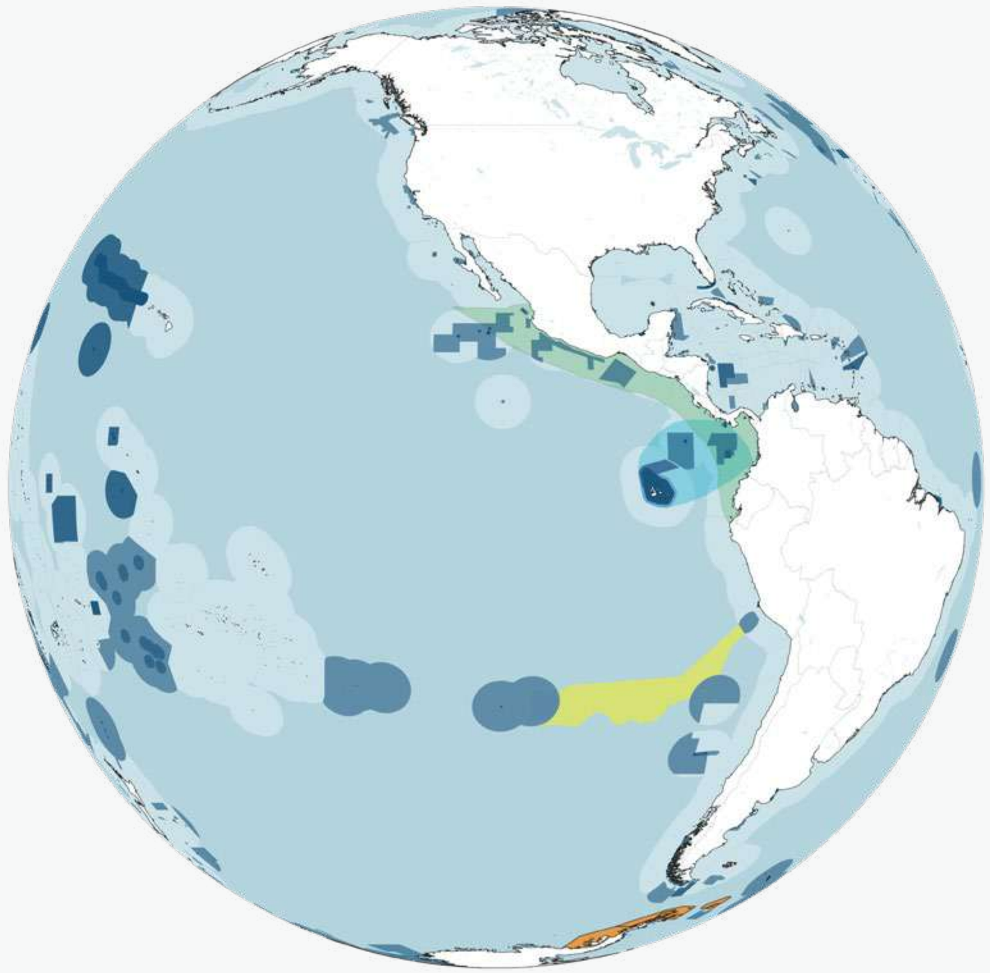
FIGURE 9

Map of current IMMAs, MPAs and MPA proposals in the Eastern Pacific and Southern Ocean. See Appendix 2 for more information on data sources.



LEGEND

- IUCN Important Marine Mammal Areas (IMMAs)
- Key Biodiversity Areas (KBAs)
- EEZ



LEGEND

- MPAs
- PACA Region (LME)
- CMAR Region
- Salas y Gómez and Nazca Redges MPA Proposal
- Antarctic Peninsula MPA proposal (CCAMLR)
- EEZ

CO-DESIGNING SOLUTIONS TO SAFEGUARD WHALE BLUE CORRIDORS

In May 2022, WWF hosted a workshop in Bogota, Colombia with 31 experts from the scientific community, civil society and governments representing 10 different countries.

The aim was to create a set of national and regional actions to promote the conservation of large whales in the Eastern Tropical and temperate Pacific from Mexico to Chile - based on concepts presented in the global *Protecting Blue Corridors* report. Discussions included ideas to strengthen transboundary governance processes to reduce the direct, indirect and cumulative impacts of human activities, promote scientific research and integrate information for improved management. The workshop explored ways to enhance the management and sustainability of ecotourism associated with whales, and contribute to its long-term economic growth responsibly.

Seven areas were highlighted as crucial to strengthening the conservation needs of whale superhighways in the Eastern Pacific, including: addressing existing research needs to fill information gaps for management; identifying national actions needed to reduce anthropogenic threats; identifying regional actions to reduce threats and improve governance; improving the access, publication and exchange of information; enhancing socio-economic benefits through sustainable tourism; building capacity of regional experts; and improving awareness and dissemination of solutions.

These concerted actions are highlighted throughout this report in order to help support connectivity conservation for whales through national and regional science and policy agendas, regional projects, marine research programs and other conservation initiatives throughout the region.

To download the workshop report visit:

WWFWHALES.ORG/2022-COLOMBIA-WORKSHOP-REPORT-EN

PROTECTING CRITICAL HABITATS OF MARINE SPECIES WITH BENEFITS TO WHALES - EASTERN TROPICAL PACIFIC MARINE CORRIDOR (CMAR)

The Eastern Tropical Pacific Marine Corridor (CMAR) initiative is a regional cooperation mechanism between Panama, Ecuador, Colombia, and Costa Rica for the conservation and sustainable use of marine biodiversity and includes a proposed network of marine protected areas covering an extent of approximately 500,000 km^2. Contained within CMAR are some of the world's most important migratory routes for whales, sea turtles, sharks and rays. Its implementation will help protect threatened endemic, native and migratory species in the region, including blue, Bryde's and sperm whales, along with a range of dolphin species.[245] Recently, the Revillagigedo National Park in Mexico joined CMAR, adding another 148,000 km^2 of no-take protected area to the CMAR network.[246,247]

This network of marine reserves follows the Cocos Ridge, an underwater mountain range that connects Costa Rica's Cocos Island National Park and Ecuador's Galápagos Marine Reserve, both UNESCO World Heritage Sites and a 700-km underwater chain of seamounts with Revillagigedo National Park in Mexico.[246,248] Many species of marine birds, invertebrates, fish, sharks, sea turtles and whales could benefit from this conservation initiative, as it further protects their critical habitats in eastern Pacific.[249,250]

CMAR also includes a new protected area, the "Hermandad Marine Reserve," that consists of two parts: a no-take zone of 30,000 km^2 to the northeast of the Galápagos Islands connecting Ecuador's waters with those of Costa Rica along the underwater seamounts of the Cocos Ridge, a key migration route for ocean-going species. Another 30,000 km^2 area is a no-longline fishing zone wrapping northwest around the existing Galápagos Marine Reserve. Networks of marine protected areas are an effective tool for restoring ocean biodiversity and ecosystem services and can play a role in mitigating climate change.[245,251–253]

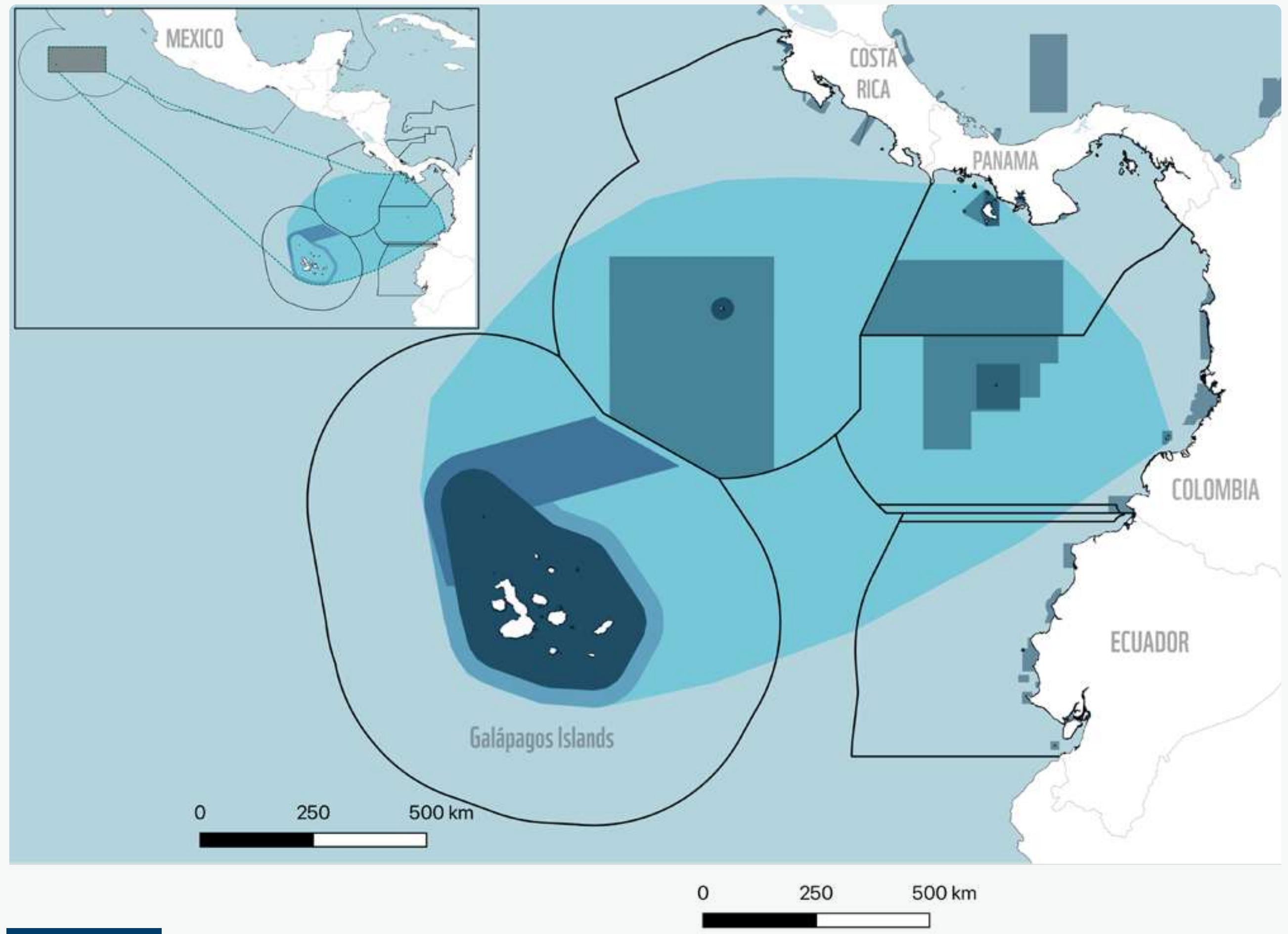


FIGURE 10

The proposed multinational protected marine corridor CMAR (bright blue), when fully implemented, will cover more than 500,000 km^2 and will help conserve many marine species including cetaceans in the Eastern Tropical Pacific.

SHIFTING SHIPPING LANES OFF THE COAST OF PERU

Peruvian waters are an important area for several species of whales, as they are transiting, feeding and breeding habitats.[254] These include blue whales, fin whales, sperm whales and southern right whales (*Eubalaena australis*). The latter is of particular concern, as the Chile–Peru subpopulation of southern right whales is Critically Endangered according to the IUCN, with less than 60 remaining adults, whose main threat is mortality due to ship collisions.[255]

Shipping routes in the southeast Pacific often overlap with whale habitat, either during the breeding season[233] or during migration.[256] This overlap, in addition to the speed of the shipping vessels, puts whales at risk of harmful collisions and it has received little attention in conservation management.[257] Due to projections of the region's trade growth with East Asia, researchers predict an increase in maritime traffic density in the near future, with the consequent increase in the probability of ship strikes.

However, the potential risk of ship strikes is still a non-quantified threat for cetaceans within Peruvian waters.[257] Evidence from neighbouring countries supports the need to address this issue through preventive measures, such as the rerouting of marine traffic, especially in areas of aggregation in northern Peruvian waters. [233]

Three Traffic Separation Schemes within the jurisdictional waters of Peru are being proposed to help reduce ship strikes. This system would be recommended for use by all vessels, after being adopted by the IMO, with the exception of national vessels engaged in fishing, hydrocarbon and tourism activities that have the corresponding permit granted by the government of Peru, and areas established for the activity.

TAKING A MULTI-POLICY APPROACH TO PROTECT MIGRATION

Most of the countries in the region are signatories to the main international conventions related to the conservation and sustainable use of marine resources. They also have developed a regional institutional framework through binding instruments, particularly in the southeast Pacific. Despite this, institutional weaknesses both nationally and regionally persist. Several action plans for species such as humpback and blue whales have been developed, as well as networks of MPAs that promote marine management through capacity building, scientific research and promoting the exchange of experiences. However, in many cases these plans are out of date and require review and strengthening.

Notwithstanding these deficiencies in the conservation of great whales, regional institutionalism constitutes an opportunity. In the southeast Pacific there is a specialized maritime agency, the Permanent Commission of the South Pacific (CPPS), which is, among other things, the technical secretariat of the United Nations Environment Programme's Action Plan for the Conservation of Marine Mammals in the Southeast Pacific, a management instrument created specifically to promote the conservation of these species and their habitats. There is no such specialized regional institution in Central America nor an action plan for marine mammals, but other national or regional institutions could assume that role.

Several initiatives in the region are aimed at strengthening the management of MPAs and migratory species, such as the CMAR and the UNESCO World Heritage Sites and Biosphere Reserves. In 2012, the CBD Secretariat led a scientific process to describe 21 EBSAs in the eastern tropical Pacific.[259]

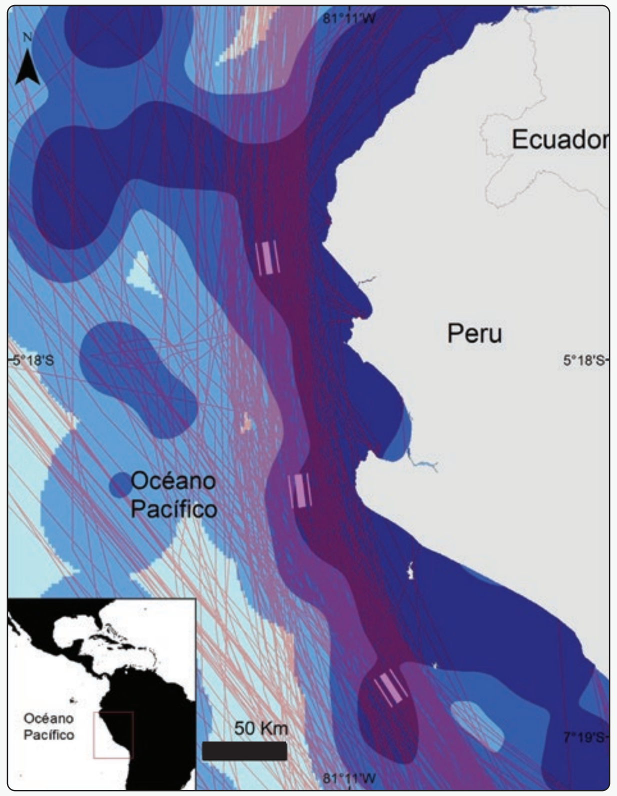


FIGURE 11

The Traffic Separation Scheme proposed for the Pacific Coast of Peru is defined in the light red areas with the lines showing vessel traffic.[258]

CASE STUDY: PROTECTING CRITICAL OCEAN HABITATS IN SOUTHERN CHILE WITH INDIGENOUS COMMUNITIES

In recent years, Chile has protected a significant area of the country's EEZ (42.4 per cent). However, only 5 per cent is in coastal areas. In the Chiloé Marine Ecoregion in southern Chile, only 0.11 per cent of this critical habitat is managed or protected.

In 2008, the Chilean government created a category of protected areas called Native Peoples' Marine Coastal Spaces (ECMPOs). These are coastal and marine areas designated by the government's Undersecretary of Fisheries and Aquaculture (SUBPESCA) and entrusted to Indigenous groups to use and administer.

Over the last decade, WWF-Chile has worked to identify and advocate for effective management of MPAs including working with Indigenous communities in Chiloé and Guafo Islands.[260]

Currently, 11 Mapuche-Huilliche communities on Chiloé Island have created and administered the Wafo Wapi Coastal Marine Area of Guafo Island, located 40 km southeast of Chiloé Island. This area is recognized for its high biological productivity, great ecological value and presence of highly migratory, emblematic and endangered marine species, such as the blue whale.

The blue whale holds great cultural value for Mapuche-Huilliche communities, which regard this species as a ferry that transports their ancestor spirits around the island waters. The ECMPO area consists of the entire coastal marine area, from the coastline to 12 miles around the island, and covers 299,000 km².

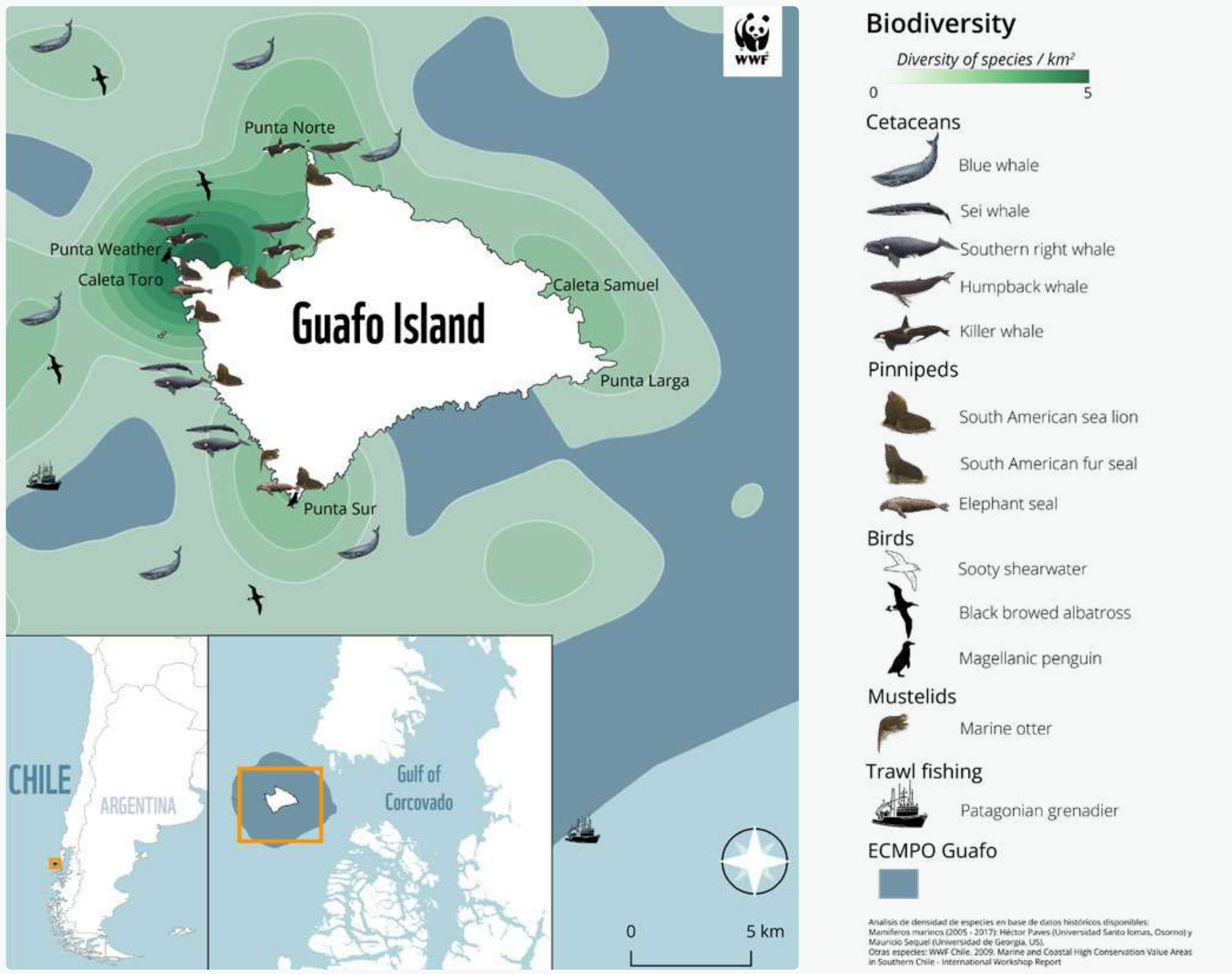


FIGURE 12

Marine biodiversity found around Guafo Island including important habitat for blue whales.

© Oliver Scholey/ Hector Skevington-Postles / Silverback / Netflix

FOR WHALE CONSERVATION AND RECOVERY, HAVING AN INTERNATIONAL BODY WITH THE COMPETENCY TO DESIGNATE MPAS IN ABNJ IS A KEY AMBITION.

AREAS BEYOND NATIONAL JURISDICTION

The global ocean can be divided into areas within the national jurisdiction of states (the Exclusive Economic Zone), usually extending 200 nautical miles (370 km) offshore, and those in international waters, called "the high seas," or more formally, Areas Beyond National Jurisdiction (ABNJ). Approximately 61 per cent of the sea surface is defined as ABNJ.

Whale conservation in ABNJ is highly challenging, since:

- **Marine mammals are highly mobile and often occur in the high seas;**[75]
- **There is still limited knowledge of the distribution of many species; and**
- **Only limited mechanisms exist for conservation and management in these areas.**[261,262]

CONSERVATION OPPORTUNITY

GLOBAL OCEANS TREATY - A NEW UN AGREEMENT ON BIODIVERSITY BEYOND NATIONAL JURISDICTION (BBNJ)

Although it is still a legal instrument in development, the new agreement on Biodiversity Beyond National Jurisdiction (BBNJ) will lay the foundations for the future management of marine biodiversity in ABNJ. The objective of this agreement is "to ensure the long-term conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction through effective implementation of the relevant provisions of the Convention and further international cooperation and coordination".[263] The agreement is based on several principles such as common heritage, equity, precaution, ecosystem and integration approaches.

There are four main components to this agreement:

1. Marine genetic resources, including questions on the sharing of benefits;
2. Area-based management tools, including MPAs;
3. Environmental impact assessments; and
4. Capacity-building and transfer of marine technology.

A strong BBNJ agreement is essential because whale migration can occur between ABNJ and national waters and is subject to a variety of threats; thus, protection measures are needed to address cumulative impacts. For whale conservation and recovery, having an international body with the competency to designate MPAs in ABNJ is a key ambition.

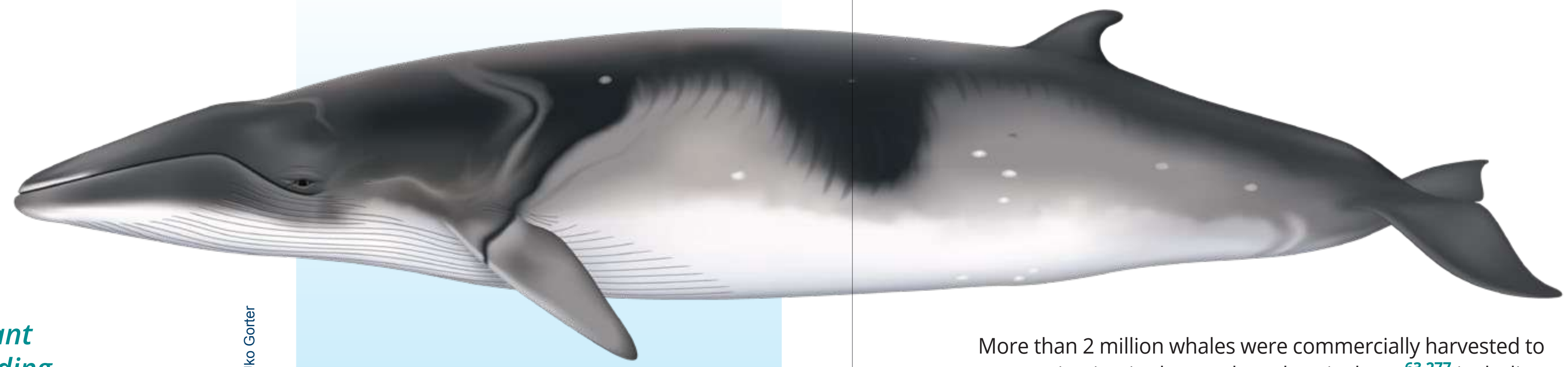
The agreement can provide the framework for the "enhanced cooperation" needed between states and international bodies to ensure the conservation and recovery of whales. As whales migrate across jurisdictions, a large number of individual coastal, flag and port states are involved and these need to share the ambition if effective action is to be taken with the myriad of sub-regional, regional and global bodies across multiple sectors of maritime activity.

This new agreement will complement existing international agreements dealing with high seas fisheries, deep-sea mining (should it be allowed to occur), pollution and conservation, and will therefore set the basis for a holistic, integrated and ecosystem-based governance of the ocean.

A Conference of the Parties (COP), likely to be established by the BBNJ agreement, would have the responsibility to foster enhanced cooperation not only between states but between the bodies established by various other agreements. This would address a key concern of states that "silo" decision-making by sectoral bodies is unhelpful to achieve necessary conservation and cooperation outcomes.

WWF is proposing that the BBNJ COP be given the responsibility of delegation to establish regional arrangements that would be given the mandate to implement the provisions of the BBNJ agreement (including designating high seas MPAs and facilitating enhanced cooperation). Such a regional delegation of global responsibilities would be done in response to a request from states with an interest in the conservation and sustainable use of ABNJ biodiversity in that region, where "region" is at the scale of ocean basins – seven globally – being the scale at which ecological, commercial and diplomatic interests best align.[1]

ANTARCTIC PENINSULA AND SOUTHERN OCEAN


Antarctic Minke Whale © Uko Gorter

The Antarctic Peninsula is an important foraging area for whale species including humpback, minke, fin, southern right and blue whales.[53] Here, they feed on Antarctic krill, their main prey in the Southern Ocean.

Krill are small, semi-transparent crustaceans and a vital component of the Antarctic ecosystem. They are a main source of food for many mammals such as seals and whales, as well as birds and fish.[264] There are around 380 million tonnes of these shrimp-like crustaceans in the Southern Ocean, similar to the total weight of human life on the planet.[265] They live for about seven years and are no larger than a little finger. Past studies indicate that krill survival and lifecycle are directly linked to fluctuations in sea ice and have already revealed a decline in krill abundance.[266]

During summer months, whales generally feed in the upper 100 metres, and in autumn between the surface and as deep as 400 metres.[267–271] Recovering humpback whale populations require lots of krill, but this is potentially in conflict with human demands for krill.

The Gerlache and Bransfield Straits along with the adjacent bays (e.g. Wilhelmina, Andvord and Flandres) are the most important feeding areas for baleen whales around the Antarctic Peninsula.[268,272,273] These areas are used throughout the summer and become the exclusive feeding habitat in autumn as sea ice develops and krill move inshore in autumn.[274,275] For example, in one day, more than 500 humpback whales and 2.3 million tonnes of krill were measured in Wilhelmina in May 2009.[273,276] Feeding behaviour is spatially and temporally clustered as krill are not uniformly distributed. Tagging studies and surveys have shown high concentrations of whales in May and June and animals remaining around the peninsula into July.[271,275]

THE ANTARCTIC KRILL FISHERY, WITH A TOTAL 2020 CATCH OF 450,000 TONNES, CURRENTLY OPERATES WITHOUT FINE-SCALE INFORMATION ON WHALE MOVEMENT, BEHAVIOUR AND PREY REQUIREMENT.[282]

CONSERVATION CHALLENGES

20TH CENTURY COMMERCIAL WHALING

During the 20th century, unchecked commercial whaling dramatically reduced whale populations throughout the Southern Ocean, driving many species to the brink of extinction. The international community has long-since recognized the importance of protecting whales in the Southern Ocean, with the IWC specifically prohibiting commercial whaling through a moratorium on commercial whaling in 1982 and the establishment of the Southern Ocean Whale Sanctuary in 1994.

More than 2 million whales were commercially harvested to near extinction in the southern hemisphere,[63,277] including blue, fin, right, humpback, sei, minke and sperm whales taken from oceanic and coastal waters. Throughout the Southern Ocean, more than 725,000 fin, 400,000 sperm, 360,000 blue, 200,000 sei and 200,000 humpback whales were killed during this time.[63]

A CHANGING CLIMATE

The Western Antarctic Peninsula is a hotspot of global environmental change. Climate change is having an increasing impact, warming the ocean and causing it to become more acidic.[278] Projected warming, ocean acidification, reduced seasonal sea-ice extent and continued loss of sea ice directly and indirectly affect wildlife habitats and populations. Sea ice is critical habitat for Antarctic krill.[100] Modelling predicts that suitable krill habitat, as well as krill populations, will shift southward by the end of the 21st century.[100,279]

For baleen whales feeding almost exclusively on krill – such as humpbacks, fin, Antarctic blue and Antarctic minke whales – these southward shifts in krill distribution may impose high energetic costs on migrating whales, with effects on body condition, reproductive fitness and population abundance.[101]

GROWING INDUSTRIAL KRILL FISHING

Historically, industrial krill fishing occurred around the entire continent of Antarctica. This led to the establishment of CCAMLR in the 1980s.

Currently, CCAMLR does not include information on climate change or fine scale krill distribution in its assessment of risks to manage krill fisheries. Whales are delegated to management under the IWC and are not considered in ecosystem-based management decisions related to commercial fishing and long-term monitoring under the CCAMLR Ecosystem Monitoring Program (CEMP). While CEMP focuses on land predators, WWF and others have called for the program to be modernised so that it includes whales and seals as part of its future monitoring and management efforts.[53]

In recent years, krill fishing has primarily taken place in the Antarctic Peninsula and Scotia Arc where catches are increasing in critical habitats for eastern Pacific humpback whales. Commercial krill fishing is the largest in the southern hemisphere. Unlike most of the world's large fisheries it has scope to expand[266] and could become the largest fishery of any type.[280] Industrial krill fisheries that operate along the Antarctic Peninsula overlap with important humpback whale foraging areas, increasing risks of bycatch and competition for krill.[275,281]


© Conor Ryan

FIGURE 13

At the 2022 CCAMLR meeting, Norway reported that humpback whales were killed as bycatch in Industrial krill fishing operations undertaken by Aker BioMarine for a second straight year. Scientists and WWF are calling for a review of their fishing nets as there are increasing concerns of whale, seabird and seal bycatch that may be underreported. Photo: IWC SC/68D/HIM/04 [283]

CONSERVATION OPPORTUNITIES

A SOUTHERN OCEAN NETWORK OF MPAS – HELPING THE RECOVERY AND CONSERVATION OF WHALES

The Southern Ocean covers 10 per cent of the world's ocean and includes some of the most productive marine areas in the world.

In protected areas of the ocean, activities are managed, limited or entirely prohibited. Antarctic ocean life is conserved through coordinated international management by CCAMLR, which can make binding consensus decisions about controlling the use of marine living resources.

CCAMLR has committed to the creation of a representative system of MPAs throughout the Southern Ocean.[284] Implementing effective MPAs will help conserve important Antarctic biodiversity including whales. They can also be used as a reference area to help monitor and understand the effects of fishing outside these regions, as well as the impacts of climate change on the Antarctic ecosystem.

IMPROVING SPATIAL DISTRIBUTION AND MANAGEMENT OF THE KRILL FISHERY

The fishery for Antarctic krill is managed by CCAMLR under an ecosystem-based framework according to which fishing should not interfere with the population growth of Antarctic krill predators.[285] Nonetheless, potential competition between fisheries and krill predators, including baleen whales, is concerning.[281,286–289] Krill catches have become more concentrated,[281,290] raising concerns about how local depletion of krill impacts predators.[281,289] CCAMLR recognized that this necessitates a smaller-scale management approach and designated "Small Scale Management Units" (16,000 km^2 to 440,000 km^2). However, catches are still managed in the much larger "subareas" (658,730km^2 to 1,033,248 km^2 for Subareas 48.1-48.4).

Consequently, there is a mismatch between the spatial and temporal scale at which krill fisheries are currently managed, and that at which fisheries operate and predators forage. There is a clear and urgent need to better understand potential interactions between baleen whales and the krill fishery. This involves understanding the dynamics and typical spatial scales, both of foraging whales and fishing vessels, implementing the Antarctic Peninsula MPA to reduce interactions.

TECHNOLOGIES TO UNCOVER THE LIVES OF ANTARCTIC WHALES

New technologies are allowing us to study whales and the ocean in new ways. Over recent years, WWF has supported field work such as using digital tags and drones to better understand how and where whales feed to uncover their favorite hotspots along the Antarctic Peninsula.[53] It gives us a window into their world, to understand the health of populations, how they are affected by climate change, and how we might protect their critical ocean habitats worldwide.

Marine conservation that makes a difference takes collaboration. Long-time science partners from University of California Santa Cruz (UCSC) with others from Stanford University published research in the journal Nature.[58] Using this new toolbox of technologies, including over 300 digital tags the size of an iPhone with suction cups, they analyzed an array of information on baleen whales such as blue, fin, humpback and minke whales. Baleen whales feed by gulping a large amount of water and filtering it through their mouths' fringed baleen plates until only their prey remains. It turns out, an individual blue whale eats an average of 16 tons of food every day — about three times more than scientists had thought.[58]

One area of focus was on the Southern Ocean. Here, baleen whales devour up to 30 percent of their body weight in krill each day. Previous estimates suggested baleen whales consume less than 5 percent of their body weight daily.[58]

Importantly, after all of this eating, comes pooping. Recently, scientists have realized that this helps fertilize our oceans and boosts the growth of phytoplankton, tiny life forms at the bottom of the marine food web that are eaten by krill. It's another example of the important relationships and dependencies between predator and prey.

Researchers feel that if we restore whale populations to pre-whaling levels, we'll restore a huge amount of lost function to ocean ecosystems. It's helping nature help itself, and all of us who depend on it.[291]

APPENDIX 1 SATELLITE TELEMETRY DATA – EASTERN PACIFIC OCEAN

SPECIES	AREA	NUMBER OF TRACKS	CONTRIBUTORS	SOURCE
Blue whales	**Eastern North Pacific**	**189**	**Daniel Palacios (Oregon State University)**	Mate, B. R., Lagerquist, B. A. & Calambokidis, J. MOVEMENTS OF NORTH PACIFIC BLUE WHALES DURING THE FEEDING SEASON OFF SOUTHERN CALIFORNIA AND THEIR SOUTHERN FALL MIGRATION1. Mar. Mamm. Sci. 15, 1246–1257 (1999) Bailey, H., Mate, B. R., Palacios, D. M., Irvine, L., Bograd, S. J. & Costa, D. P. Behavioural estimation of blue whale movements in the Northeast Pacific from state-space model analysis of satellite tracks. Endanger. Species Res. 10, 93–106 (2010). Irvine, L. M., Mate, B. R., Winsor, M. H., Palacios, D. M., Bograd, S. J., Costa, D. P. & Bailey, H. Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. PLoS One 9, (2014).
Blue whales	**Chile**	**10**	**Publication supplement.**	Hucke-Gaete, R., Bedriñana-Romano, L., Viddi, F. A., Ruiz, J. E., Torres-Florez, J. P. & Zerbini, A. N. From Chilean Patagonia to Galapagos, Ecuador: Novel insights on blue whale migratory pathways along the Eastern South Pacific. PeerJ 2018, 1–22 (2018).
Blue whales	**Chile**	**15**	**Publication supplement.**	Bedriñana-Romano, L., Hucke-Gaete, R., Viddi, F. A., Johnson, D., Zerbini, A. N., Morales, J., Mate, B. & Palacios, D. M. Defining priority areas for blue whale conservation and investigating overlap with vessel traffic in Chilean Patagonia, using a fast-fitting movement model. Sci. Rep. 11, 1–16 (2021).
Fin whales	**Chile**	**6**	**Natalya Hernández**	Sepúlveda, M., Pérez-Álvarez, M. J., Santos-Carvallo, M., Pavez, G., Olavarría, C., Moraga, R. & Zerbini, A. N. From whaling to whale watching: Identifying fin whale critical foraging habitats off the Chilean coast. Aquat. Conserv. 28, 821–829 (2018).
Humpback whales	**Eastern North Pacific - Hawaii**	**49**	**Daniel Palacios (Oregon State University)**	Mate, B. R., Gisiner, R. & Mobley, J. Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry. Can. J. Zool. (1998). Mate, B., Mesecar, R. & Lagerquist, B. The evolution of satellite-monitored radio tags for large whales: One laboratory's experience. Deep Sea Res. Part 2 Top. Stud. Oceanogr. 54, 224–247 (2007). Tagged in Hawaii. Years: 1994-2000
Humpback whales	**Eastern North Pacific - Southeast Alaska**	**46**	**Daniel Palacios (Oregon State University)**	Mate, B., Mesecar, R. & Lagerquist, B. The evolution of satellite-monitored radio tags for large whales: One laboratory's experience. Deep Sea Res. Part 2 Top. Stud. Oceanogr. 54, 224–247 (2007). Palacios, D.M., B.R. Mate, C.S. Baker, C.E. Hayslip, T.M. Follett, D. Steel, B.A. Lagerquist, L.M. Irvine, and M.H. Winsor. Tracking North Pacific Humpback Whales To Unravel Their Basin-Wide Movements. Final Technical Report. Prepared for Pacific Life Foundation. Marine Mammal Institute, Oregon State University. Newport, Oregon, USA. 30 June 2019. 58 pp. doi:10.5399/osu/1117. (2019). ***https://ir.library.oregonstate.edu/concern/technical_reports/z890s0924*** Oregon State University, unpublished. Tagged in SE Alaska. Years: 1997, 2014, 2015
Humpback whales	**Eastern North Pacific - Mexico**	**17**	**Daniel Palacios (Oregon State University)**	Lagerquist, B. A., Mate, B. R., Ortega-Ortiz, J. G., Winsor, M. & Urbán-Ramirez, J. Migratory movements and surfacing rates of humpback whales (*Megaptera novaeangliae*) satellite tagged at Socorro Island, Mexico. Mar. Mamm. Sci. 24, 815–830 (2008). Tagging done in Baja California, Mexico (1998; unpublished) and in the Revillagigedo Islands, Mexico (2003; Lagerquist et al. 2008). Oregon State University, unpublished.
Humpback whales	**Southern Ocean**	**378**	**Ryan Reisinger (University of Southampton) and collaborators**	Reisinger RR, Friedlaender AS, Zerbini AN, Palacios DM, Andrews-Goff V, Dalla Rosa L, Double M, Findlay K, Garrigue C, How J, Jenner C, Jenner M-N, Mate B, Rosenbaum HC, Seakamela SM, and Constantine R. Combining regional habitat selection models for large-scale prediction: circumpolar habitat selection of Southern Ocean humpback whales. Remote Sensing (2021).
Southern right whales	**South Africa**	**21.00**	**Daniel Palacios (Oregon State University),** **Els Vermuelen (University of Pretoria)**	Mate, B. R., Best, P. B., Lagerquist, B. A. & Winsor, M. H. Coastal, offshore, and migratory movements of South African right whales revealed by satellite telemetry. Mar. Mamm. Sci. 27, 455–476 (2011).

APPENDIX 2 MARINE AND ENVIRONMENTAL DATA

DATA LAYERS DISPLAYED IN MAPS AND INFOGRAPHICS	SOURCE
Marine Protected Areas	UNEP-WCMC and IUCN. Protected Planet: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-based Conservation Measures (WD-OECM) [Online], December 2022, Cambridge, UK: UNEP-WCMC and IUCN (2022). Available at ***www.protectedplanet.net.*** For CCAMLR MPA data layers, special thanks to Cassandra Brooks, University of Colorado, Boulder (USA)
IUCN Important Marine Mammal Areas (IMMAs)	IUCN Marine Mammal Protected Areas Task Force. Global Dataset of Important Marine Mammal Areas (IUCN-IMMA). December 2022. Made available under agreement on terms of use by the IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force (2022). Available at ***www.marinemammalhabitat.org/imma-eatlas***
Key Biodiversity Areas (KBAs)	BirdLife International. World Database of Key Biodiversity Areas. Developed by the KBA Partnership: BirdLife International, International Union for the Conservation of Nature, American Bird Conservancy, Amphibian Survival Alliance, Conservation International, Critical Ecosystem Partnership Fund, Global Environment Facility, Re:wild, NatureServe, Rainforest Trust, Royal Society for the Protection of Birds, Wildlife Conservation Society and World Wildlife Fund. September 2021 version (2021). Available at ***http://keybiodiversityareas.org/kba-data/request***
Other Effective Area-based Conservation Measures (OECMs)	UNEP-WCMC and IUCN. Protected Planet: The World Database on Other Effective Area-based Conservation Measures (WD-OECM) [Online], November 2021, Cambridge, UK: UNEP-WCMC and IUCN (2021). Available at ***www.protectedplanet.net***
Country Borders, Land and Sea Areas	Available at ***https://www.naturalearthdata.com/***
Country EEZs	Flanders Marine Institute. Maritime Boundaries Geodatabase: Maritime Boundaries and Exclusive Economic Zones (200NM), version 11 (2019). Downloaded from ***https://www.marineregions.org/***. Last accessed 10 February 2021. ***https://doi.org/10.14284/386***.
Climate Change Data	GISTEMP Team: GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies (2021). Dataset accessed 2021-03-22 at ***data.giss.nasa.gov/gistemp/***. Lenssen, N., G. Schmidt, J. Hansen, M. Menne, A. Persin, R. Ruedy, and D. Zyss. Improvements in the GISTEMP uncertainty model. J. Geophys. Res. Atmos., 124, no. 12, 6307-6326, doi:10.1029/2018JD029522 (2019).
Global Fishing Effort	Global Fishing Watch. Fishing effort, Version 2. Global Fishing Watch. (2021). Downloaded (19 March 2021) from ***https://globalfishingwatch.org/data-download/datasets/public-fishing-effort***.
Global Ship Traffic Data	ExactEarth Vessel Traffic Density Layers, (2015). ***https://www.exactearth.com/product-exactais-density-maps***
Species Probability of Occurrence	Kaschner, K., K. Kesner-Reyes, C. Garilao, J. Segschneider, J. Rius-Barile, T. Rees, and R. Froese. AquaMaps: Predicted range maps for aquatic species. World Wide Web electronic publication, www.aquamaps.org, version 10/2019 (final) (2019). Last accessed 22 December 2022.

All data was visualised using R and QGIS 3.

REFERENCES

1. Johnson, C. M., Reisinger, R. R., Palacios, D. M., Friedlaender, A. S., Zerbini, A. N., Willson, A., Lancaster, M., Battle, J., Graham, A., Cosandey-Godin, A., Jacob, T., Felix, F., Grilly, E., Shahid, U., Houtman, N., Alberini, A., Montecinos, Y., Najera, E. & Kelez, S. Protecting Blue Corridors - Challenges and solutions for migratory whales navigating national and international seas (2022). WWF-International, Switzerland. at <***https://doi.org/10.5281/ZENODO.6196131***>

2. Kaschner, K. Kesner-Reyes, K. Garilao, C. Segschneider, J. Rius-Barile, J. Rees, T. Froese, R. AquaMaps: Predicted range maps for aquatic species. AquaMaps (2019). at <***https://www.aquamaps.org***>

3. Bailey, H., Mate, B. R., Palacios, D. M., Irvine, L., Bograd, S. J. & Costa, D. P. Behavioural estimation of blue whale movements in the Northeast Pacific from state-space model analysis of satellite tracks. Endanger. Species Res. 10, 93–106 (2010).

4. Blevins, C., Busquets-Vass, G., Pardo, M. A., Gendron, D., Jacobsen, J. K., Gómez-Díaz, F., Pérez-Puig, H., Ortega-Ortiz, C. D., Heckel, G., Urbán R, J., Viloria-Gómora, L. & Newsome, S. D. Sex- and age-specific migratory strategies of blue whales in the northeast Pacific Ocean. Front. Mar. Sci. 9, (2022).

5. Busquets-Vass, G., Newsome, S. D., Pardo, M. A., Calambokidis, J., Aguíñiga-García, S., Páez-Rosas, D., Gómez-Gutiérrez, J., Enríquez-Paredes, L. M. & Gendron, D. Isotope-based inferences of the seasonal foraging and migratory strategies of blue whales in the eastern Pacific Ocean. Mar. Environ. Res. 163, 105201 (2021).

6. Palacios, D. M., Bailey, H., Becker, E. A., Bograd, S. J., DeAngelis, M. L., Forney, K. A., Hazen, E. L., Irvine, L. M. & Mate, B. R. Ecological correlates of blue whale movement behavior and its predictability in the California Current Ecosystem during the summer-fall feeding season. Mov Ecol 7, 26 (2019).

7. Félix, F., Botero, N. & Falconí, J. Observation of a blue whale (*Balaenoptera musculus*) feeding in coastal waters of Ecuador. Lat. Am. J. Aquat. Mamm. 193–197 (2007). doi:10.5597/lajam00125

8. Hucke-Gaete, R., Bedriñana-Romano, L., Viddi, F. A., Ruiz, J. E., Torres-Florez, J. P. & Zerbini, A. N. From Chilean Patagonia to Galapagos, Ecuador: Novel insights on blue whale migratory pathways along the Eastern South Pacific. PeerJ 2018, 1–22 (2018).

9. Torres-Florez, J. P., Olson, P. A., Bedriñana-Romano, L., Rosenbaum, H., Ruiz, J., LeDuc, R. & Hucke-Gaete, R. First documented migratory destination for eastern South Pacific blue whales. Mar. Mamm. Sci. (2015). at <***http://onlinelibrary.wiley.com/doi/10.1111/mms.12239/full***>

10. Torres-Florez, J. P., Hucke-Gaete, R., LeDuc, R., Lang, A., Taylor, B., Pimper, L. E., Bedriñana-Romano, L., Rosenbaum, H. C. & Figueroa, C. C. Blue whale population structure along the eastern South Pacific Ocean: evidence of more than one population. Mol. Ecol. 23, 5998–6010 (2014).

11. Jiménez López, M. E., Palacios, D. M., Jaramillo Legorreta, A., Urbán R, J. & Mate, B. R. Fin whale movements in the Gulf of California, Mexico, from satellite telemetry. PLoS One 14, e0209324 (2019).

12. Falcone, E. A., Keene, E. L., Keen, E. M., Barlow, J., Stewart, J., Cheeseman, T., Hayslip, C. & Palacios, D. M. Movements and residency of fin whales (*Balaenoptera physalus*) in the California Current System. Mamm. Biol. (2022). doi:10.1007/s42991-022-00298-4

13. Pérez-Alvarez, M., Kraft, S., Segovia, N. I., Olavarría, C., Nigenda-Morales, S., Urbán R., J., Viloria-Gómora, L., Archer, F., Moraga, R., Sepúlveda, M., Santos-Carvallo, M., Pavez, G. & Poulin, E. Contrasting phylogeographic patterns among Northern and Southern Hemisphere fin whale populations with new data from the southern pacific. Front. Mar. Sci. 8, (2021).

14. Felix, F., Haase, B., Teran, C., Pozo, M. & Burneo, S. First record of a fin whale (*Balaenoptera physalus*) in coastal waters of Ecuador in a century. JCRM 23, 141–147 (2022).

15. Cortes, F. A. T., Gutiérrez, J., Alvarado-Rybak, M., Henríquez, A., Leichtle, J., Follador, N., Abarca, P., Calderón, C., Peña, C., Aravena, P., Henríquez, A., Rodríguez, D., Sánchez, C. & Pincheira, B. Report of two fin whale (*Balaenoptera physalus*) stranding associated with ship strike in central-south coast of Chile. Lat. Am. J. Aquat. Mamm. 15, 8–14 (2020).

16. Toro, F., Vilina, Y. A., Capella, J. J. & Gibbons, J. Novel coastal feeding area for eastern South Pacific fin whales (*Balaenoptera physalus*) in mid-latitude humboldt current waters off Chile. Aquat. Mamm. 42, 47 (2016).

17. Pacheco, A. S., Villegas, V. K., Riascos, J. M. & Van Waerebeek, K. Presence of fin whales (*Balaenoptera physalus*) in Mejillones Bay, a major seaport area in northern Chile. Rev. Biol. Mar. Oceanogr. 50, 383–389 (2015).

18. Acevedo, J., O'Grady, M. & Wallis, B. Sighting of the fin whale in the Eastern Subtropical South Pacific: Potential breeding ground? Rev. Biol. Mar. Oceanogr. 47, 559–563 (2012).

19. Pérez, M. J., Thomas, F., Uribe, F., Sepúlveda, M., Flores, M. & Moraga, R. Fin whales (*Balaenoptera physalus*) feeding on Euphausia mucronata in nearshore waters off north-central Chile. Aquat. Mamm. 32, 109 (2006).

20. Sepúlveda, M., Pérez-Álvarez, M. J., Santos-Carvallo, M., Pavez, G., Olavarría, C., Moraga, R. & Zerbini, A. N. From whaling to whale watching: Identifying fin whale critical foraging habitats off the Chilean coast. Aquat. Conserv. 28, 821–829 (2018).

21. Martínez-Loustalot, P., Audley, K., Cheeseman, T., De Weerdt, J., Frisch-Jordán, A., Guzón, O., Olio, M., Ortega-Ortiz, C. D., Ransome, N., Villegas-Zurita, F. & Urbán R., J. Towards the definition of the humpback whale population units along the Mexican and Central American coasts in the Pacific Ocean. Mar. Mamm. Sci. (2022). doi:10.1111/mms.12980

22. Pelayo-González, L., Herra-Miranda, D., Pacheco-Polanco, J. D., Guzmán, H. M., Goodman, S. & Oviedo, L. Decreases in encounter rate of endangered Northeast Pacific humpback whales in Southern Costa Rica: Possible changes in migration pattern due to warming events. Front. Mar. Sci. 9, (2022).

23. Curtis, K. A. Abundance of humpback whales (*Megaptera novaeangliae*) wintering in Central America and southern Mexico from a one-dimensional spatial capture-recapture model. Preprint at ***https://doi.org/10.25923/9CQ1-RX80*** (2022)

24. Cantor, M., Whitehead, H., Gero, S. & Rendell, L. Cultural turnover among Galápagos sperm whales. Royal Society Open Science 3, 160615 (2016).

25. Hoelzel, A. R., Sarigol, F., Gridley, T. & Elwen, S. H. Natal origin of Namibian grey whale implies new distance record for in-water migration. Biol. Lett. 17, 20210136 (2021).

26. Baird, R. W., James, J., Mata, C. & Hughes, M. Two Gray Whale (*Eschrichtius robustus*) Sightings off Hawai'i Island: The First Records for the Central Tropical Pacific. Aquatic Mammals 48, 432–435 Preprint at ***https://doi.org/10.1578/am.48.5.2022.432*** (2022)

27. Scheinin, A. P., Kerem, D., MacLeod, C. D., Gazo, M., Chicote, C. A. & Castellote, M. Gray whale (*Eschrichtius robustus*) in the Mediterranean Sea: anomalous event or early sign of climate-driven distribution change? Mar. Biodivers. Rec. 4, e28 (2011).

28. Delphis, O. Wally, a gray whale in the Mediterranean Sea. Oceanomare Delphis (2021). at <***https://www.oceanomaredelphis.org/en/wally-a-gray-whale-in-the-mediterranean-sea/***>

29. Reuters. Lost in the Mediterranean, a starving grey whale must find his way home soon. Reuters (2021). at <***https://www.reuters.com/business/environment/lost-mediterranean-starving-grey-whale-must-find-his-way-home-soon-2021-05-07/***>

30. Gendron, D., Lanham, S. & Carwardine, M. North Pacific right whale (*Eubalaena glacialis*) sighting South of Baja California. Aquat. Mamm. 31–34 (1999). at <***https://aquaticmammalsjournal.org/share/AquaticMammalsIssueArchives/1999/AquaticMammals_25-01/25-01_Gendron.pdf***>

31. Rowlett, R. A., Green, G. A., Bowlby, C. E. & Smultea, M. A. The First Photographic Documentation of a Northern Right Whale off Washington State. Northwest. Nat. 75, 102–104 (1994).

32. Herman, L. M., Baker, C. S., Forestell, P. H. & Antinoja, R. C. Right Whale *Balaena glacialis* Sightings Near Hawaii: A Clue to the Wintering Grounds? Marine Ecology Progress Series 2, 271–275 Preprint at ***https://doi.org/10.3354/meps002271*** (1980)

33. Rowntree, V., Darling, J., Silber, G. & Ferrari, M. Rare sighting of a right whale (*Eubalaena glacialis*) in Hawaii. Can. J. Zool. 58, 309–312 (1980).

34. García-Cegarra, A. M., Malebran, M. & Van Waerebeek, K. Antofagasta Region in northern Chile, a potential nursing ground for the Southern right whale *Eubalaena australis*. Latin American Journal of Aquatic Mammals (2021). doi:10.5597/lajam00270

35. Carvalho, K. S., Smith, T. E. & Wang, S. Bering Sea marine heatwaves: Patterns, trends and connections with the Arctic. J. Hydrol. 600, 126462 (2021).

36. Insley, S. J., Halliday, W. D., Mouy, X. & Diogou, N. Bowhead whales overwinter in the Amundsen Gulf and Eastern Beaufort Sea. Royal Society Open Science 8, 202268 (2021).

37. Stafford, K. M. in Ethology and Behavioral Ecology of Mysticetes (eds. Clark, C. W. & Garland, E. C.) 277–295 (Springer International Publishing, 2022). doi:10.1007/978-3-030-98449-6_12

38. Häussermann, V., Gutstein, C. S., Bedington, M., Cassis, D., Olavarria, C., Dale, A. C., Valenzuela-Toro, A. M., Perez-Alvarez, M. J., Sepúlveda, H. H., McConnell, K. M., Horwitz, F. E. & Försterra, G. Largest baleen whale mass mortality during strong El Niño event is likely related to harmful toxic algal bloom. PeerJ 5, e3123 (2017).

39. Biggs, D. C., Durkacz, S. M., Martin, L. M., Narvaez, M., De La Garza, A., Lombraña, Z. & Santos, M. Bryde's whales (*Balaenoptera brydei*) in an area of upwelling off Isla San Cristóbal, Galápagos. Neotropical Biodiversity 3, 189–195 (2017).

40. Tershy, B. R. Body Size, Diet, Habitat Use, and Social Behavior of Balaenoptera Whales in the Gulf of California. J. Mammal. 73, 477–486 (1992).

41. Rasmussen, K. & Palacios, D. M. Bryde's whale (*Balaenoptera edeni*) aggregation area in the Gulf of Chiriqui, Panama. Revista de Biología Tropical

42. Dorsey, E. M. Exclusive adjoining ranges in individually identified minke whales (*Balaenoptera acutorostrata*) in Washington state. Can. J. Zool. 61, 174–181 (1983).

43. Dorsey, E. M., Stern, S. J., Hoelzel, A. R. & Jacobsen, J. Minke whales (*Balaenoptera acutorostrata*) from the west coast of North America: individual recognition and small-scale site fidelity. Rept. Int. Whal. Commn. , Special 357–368 (1990). at <***https://www.researchgate.net/profile/Sally-Mizroch/publication/291157559_Report_of_the_workshop_on_individual_recognition_and_the_estimation_of_cetacean_population_parameters/links/5807cdf008ae5ed04bfe7e78/Report-of-the-workshop-on-individual-recognition-and-the-estimation-of-cetacean-population-parameters.pdf#page=365***>

44. Towers, J. R., McMillan, C. J., Malleson, M., Hildering, J., Ford, J. K. B. & Ellis, G. M. Seasonal movements and ecological markers as evidence for migration of common minke whales photo-identified in the eastern North Pacific. J. Cetacean Res. Manag. 13, 221–229 (2013).

45. Herr, H., Kelly, N., Dorschel, B., Huntemann, M., Kock, K. H., Lehnert, L. S., Siebert, U., Viquerat, S., Williams, R., Scheidat, M., Kelly, N., Hermann, K., Linn, K., Lehnert, S., Williams, R. & Siebert, U. Aerial surveys for Antarctic minke whales (*Balaenoptera bonaerensis*) reveal sea ice dependent distribution patterns. Ecol. Evol. 9, 5664–5682 (2019).

46. Friedlaender, A. S., Joyce, T., Johnston, D. W., Read, A. J., Nowacek, D. P., Goldbogen, J. A., Gales, N. & Durban, J. W. Sympatry and resource partitioning between the largest krill consumers around the Antarctic Peninsula. Mar. Ecol. Prog. Ser. 669, 1–16 (2021).

47. Friedlaender, A. S., Halpin, P. N., Qian, S. S., Lawson, G. L., Wiebe, P. H., Thiele, D. & Read, A. J. Whale distribution in relation to prey abundance and oceanographic processes in shelf waters of the Western Antarctic Peninsula. Mar. Ecol. Prog. Ser. 317, 297–310 (2006).

48. WWF. ArcNet. WWF Arctic Programme (2021). at <***https://www.arcticwwf.org/our-priorities/nature/arcnet/***>

49. Deep-Ocean Stewardship Initiative. Ecological Connectivity: Implications for Ocean Governance. Deep-Ocean Stewardship Initiative (2020). at <***https://www.dosi-project.org/wp-content/uploads/DOSI-Connectivity_brief_Feb2020.pdf***>

50. Grebmeier, J. M., Cooper, L. W., Feder, H. M. & Sirenko, B. I. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. Prog. Oceanogr. 71, 331–361 (2006).

51. Enright, S. R., Meneses-Orellana, R. & Keith, I. The Eastern Tropical Pacific Marine Corridor (CMAR): The emergence of a voluntary regional cooperation mechanism for the conservation and sustainable use of marine biodiversity within a fragmented regional ocean governance landscape. Front. Mar. Sci. 8, (2021).

52. Martin, S. L., Ballance, L. T. & Groves, T. An Ecosystem Services Perspective for the Oceanic Eastern Tropical Pacific: Commercial Fisheries, Carbon Storage, Recreational Fishing, and Biodiversity. Frontiers in Marine Science 3, (2016).

53. Friedlaender, A. S., Modest, M. & Johnson, C. M. Whales of the Antarctic Peninsula: Science & Technology for the 21st Century - A Technical Report. (WWF and the University of California, Santa Cruz, 2018). at <***https://www.wwf.org.au/ArticleDocuments/353/WWF_UCSC_AntarcticWhales_Report2018_Web.pdf.aspx***>

54. United States Government. Ninth Summit of the Americas. United States Depart of State. (2022). at <***https://www.state.gov/summit-of-the-americas/***>

55. Government of Canada. Joint declaration on "Americas for the Protection of the Ocean" during the ninth Summit of the Americas. Government of Canada (2022). at <***https://www.dfo-mpo.gc.ca/oceans/collaboration/declaration-eng.html***>

56. Hoyt, E. Marine Protected Areas for Whales, Dolphins and Porpoises: A world handbook for cetacean habitat conservation and planning. (London: Earthscan, 2011).

57. Chami, R., Cosimano, T., Fullenkamp, C. & Oztosun, S. Nature's Solution to Climate Change. Finance and Development 56, 34–38 (2019).

58. Savoca, M. S., Czapanskiy, M. F., Kahane-Rapport, S. R., Gough, W. T., Fahlbusch, J. A., Bierlich, K. C., Segre, P. S., Di Clemente, J., Penry, G. S., Wiley, D. N., Calambokidis, J., Nowacek, D. P., Johnston, D. W., Pyenson, N. D., Friedlaender, A. S., Hazen, E. L. & Goldbogen, J. A. Baleen whale prey consumption based on high-resolution foraging measurements. Nature 599, 85–90 (2021).

59. Pearson, H. C., Savoca, M. S., Costa, D. P., Lomas, M. W., Molina, R., Pershing, A. J., Smith, C. R., Villaseñor-Derbez, J. C., Wing, S. R. & Roman, J. Whales in the carbon cycle: can recovery remove carbon dioxide? Trends Ecol. Evol. (2022). doi:10.1016/j.tree.2022.10.012

60. Simmonds, M., Nunny, L., Sangster, G. & Luksenburg, J. THE REAL AND IMMINENT EXTINCTION RISK TO WHALES, DOLPHINS AND PORPOISES: AN OPEN LETTER FROM [OVER 250] CETACEAN SCIENTISTS [3/9/2020]. (2020).

61. WWF. Urgent call by global experts for our most vulnerable whales, dolphins and porpoises worldwide. World Wide Fund for Nature - International (2020). at <***https://wwf.panda.org/wwf_news/?907716/Urgent-call-by-global-experts-for-our-most-vulnerable-whales-dolphins-and-porpoises-worldwide***>

62. Rojas-Bracho, L., Taylor, B., Booth, C., Thomas, L., Jaramillo-Legorreta, A., Nieto-García, E., Cárdenas Hinojosa, G., Barlow, J., Mesnick, S. L., Gerrodette, T., Olson, P., Henry, A., Rizo, H., Hidalgo-Pla, E. & Bonilla-Garzón, A. More vaquita porpoises survive than expected. Endanger. Species Res. 48, 225–234 (2022).

63. Rocha, R. C., Jr, Clapham, P. J., Ivashchenko, Y., Rocha, R. C., Clapham, P. J., Ivashchenko, Y., Rocha, R. C., Jr, Clapham, P. J. & Ivashchenko, Y. Emptying the Oceans: A Summary of Industrial Whaling Catches in the 20th Century. Mar. Fish. Rev. 76, 37–48 (2014).

64. Avila, I. C., Kaschner, K. & Dormann, C. F. Current global risks to marine mammals: Taking stock of the threats. Biol. Conserv. 221, 44–58 (2018).

65. Nelms, S. E., Alfaro-Shigueto, J., Arnould, J. P. Y., Avila, I. C., Bengtson Nash, S., Campbell, E., Carter, M. I. D., Collins, T., Currey, R. J. C., Domit, C., Franco-Trecu, V., Fuentes, M., Gilman, E., Harcourt, R. G., Hines, E. M., Rus Hoelzel, A., Hooker, S. K., Johnston, D. W., Kelkar, N., Kiszka, J. J., Laidre, K. L., Mangel, J. C., Marsh, H., Maxwell, S. M., Onoufriou, A. B., Palacios, D. M., Pierce, G. J., Ponnampalam, L. S., Porter, L. J., Russell, D. J. F., Stockin, K. A., Sutaria, D., Wambiji, N., Weir, C. R., Wilson, B. & Godley, B. J. Marine mammal conservation: over the horizon. Endanger. Species Res. 44, 291–325 (2021).

66. Read, A. J., Drinker, P. & Northridge, S. Bycatch of marine mammals in U.S. and global fisheries. Conserv. Biol. 20, 163–169 (2006).

67. Pirotta, V., Grech, A., Jonsen, I. D., Laurance, W. F. & Harcourt, R. G. Consequences of global shipping traffic for marine giants. Front. Ecol. Environ. 17, 39–47 (2019).

68. Schoeman, R. P., Patterson-Abrolat, C. & Plön, S. A Global Review of Vessel Collisions With Marine Animals. Frontiers in Marine Science 7, 1–25 (2020).

69. Duarte, C. M., Chapuis, L., Collin, S. P., Costa, D. P., Devassy, R. P., Eguiluz, V. M., Erbe, C., Gordon, T. A. C., Halpern, B. S., Harding, H. R., Havlik, M. N., Meekan, M., Merchant, N. D., Miksis-Olds, J. L., Parsons, M., Predragovic, M., Radford, A. N., Radford, C. A., Simpson, S. D., Slabbekoorn, H., Staaterman, E., Van Opzeeland, I. C., Winderen, J., Zhang, X. & Juanes, F. The soundscape of the Anthropocene ocean. Science 371, (2021).

70. Jepson, P. D. & Law, R. J. Persistent pollutants, persistent threats. Science 352, 1388 LP–1389 (2016).

71. Simmonds, M. P. in Marine Mammal Welfare: Human Induced Change in the Marine Environment and its Impacts on Marine Mammal Welfare (ed. Butterworth, A.) 27–37 (Springer International Publishing, 2017). doi:10.1007/978-3-319-46994-2_3

72. Albouy, C., Delattre, V., Donati, G., Frölicher, T. L., Albouy-Boyer, S., Rufino, M., Pellissier, L., Mouillot, D. & Leprieur, F. Global vulnerability of marine mammals to global warming. Sci. Rep. 10, 1–12 (2020).

73. Eguchi, T., Lang, A. R. & Weller, D. W. Eastern North Pacific gray whale calf production 1994-2022. (U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-667., 2022). doi:10.25923/4g6h-9129

74. NOAA. Gray Whale Numbers Continue Decline; NOAA Fisheries Will Continue Monitoring. NOAA Fisheries (2022). at <***https://www.fisheries.noaa.gov/feature-story/gray-whale-numbers-continue-decline-noaa-fisheries-will-continue-monitoring***>

75. Harrison, A.-L., Costa, D. P., Winship, A. J., Benson, S. R., Bograd, S. J., Antolos, M., Carlisle, A. B., Dewar, H., Dutton, P. H., Jorgensen, S. J., Kohin, S., Mate, B. R., Robinson, P. W., Schaefer, K. M., Shaffer, S. A., Shillinger, G. L., Simmons, S. E., Weng, K. C., Gjerde, K. M. & Block, B. A. The political biogeography of migratory marine predators. Nature Ecology & Evolution 2, 1571–1578 (2018).

76. United Nations. Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction. United Nations (2021). at <***https://www.un.org/bbnj/***>

77. Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta E Costa, B., Pike, E. P., Kingston, N., Laffoley, D., Sala, E., Claudet, J., Friedlander, A. M., Gill, D. A., Lester, S. E., Day, J. C., Gonçalves, E. J., Ahmadia, G. N., Rand, M., Villagomez, A., Ban, N. C., Gurney, G. G., Spalding, A. K., Bennett, N. J., Briggs, J., Morgan, L. E., Moffitt, R., Deguignet, M., Pikitch, E. K., Darling, E. S., Jessen, S., Hameed, S. O., Di Carlo, G., Guidetti, P., Harris, J. M., Torre, J., Kizilkaya, Z., Agardy, T., Cury, P., Shah, N. J., Sack, K., Cao, L., Fernandez, M. & Lubchenco, J. The MPA Guide: A framework to achieve global goals for the ocean. Science 373, eabf0861 (2021).

78. UNEP-WCMC. Marine Protected Areas. Protected Planet (2022). at <***https://www.protectedplanet.net/en/thematic-areas/marine-protected-areas***>

79. IUCN. Increasing marine protected area coverage for effective marine biodiversity conservation. in WCC 2016 Res 050 (IUCN Conservation Congress, 2016).

80. O'Leary, B. C., Winther-Janson, M., Bainbridge, J. M., Aitken, J., Hawkins, J. P. & Roberts, C. M. Effective Coverage Targets for Ocean Protection. Conservation Letters 9, 398–404 (2016).

81. High Ambition Coalition for Nature and People. High Ambition Coalition Member Countries. High Ambition Coalition for Nature and People (2021). at <***https://www.hacfornatureandpeople.org/hac-members***>

82. United Kingdom. Global Ocean Alliance: 30by30 initiative. Government of the United Kingdom (2021). at <***https://www.gov.uk/government/topical-events/global-ocean-alliance-30by30-initiative/about#global-ocean-alliance-members***>

83. Maxwell, S. M., Gjerde, K. M., Conners, M. G. & Crowder, L. B. Mobile protected areas for biodiversity on the high seas. Science 367, 252 LP–254 (2020).

84. CMS. Resolution 12.26 (Rev.13) "Improving Ways of Addressing Connectivity Conservation of Migratory Species" adopted 22 February 2020 by the 13th Conference of the Parties in Gandhinagar, India. Preprint at ***https://www.cms.int/sites/default/files/document/cms_cop13_res.12.26_rev.cop13_e.pdf*** (2020)

85. Hilty, J., Worboys, G. L., Keeley, A., Woodley, S., Lausche, B., Locke, H., Carr, M., Pulsford, I., Pittock, J., Wilson White, J., Theobald, D. M., Levine, J., Reuling, M., Watson, J. E. M., Ament, R. & Tabor, G. M. Guidelines for conserving connectivity through ecological networks and corridors. (IUCN-WCPA, 2020). doi:10.2305/IUCN.CH.2020.PAG.30.en

86. Lausche, B., Laur, A. & Collins, M. Marine Connectivity Conservation ' Rules of Thumb ' For MPA and MPA Network Design. 15 (IUCN WCPA Connectivity Conservation Specialist Group's Marine Connectivity Working Group, 2021).

87. IUCN-WCPA. Guidelines for Recognising and Reporting Other Effective Area-based Conservation Measures. (IUCN World Commission on Protected Areas, 2019).

88. Day, J., Dudley, N., Hockings, M., Holmes, G., Laffoley, D., Stolton, S. & Wells, S. Guidelines for Applying the IUCN Protected Area Management Categories to Marine Protected Areas. (IUCN, 2012). at <***https://portals.iucn.org/library/node/10201***>

89. IPCC. Special Report on the Ocean and Cryosphere in a Changing Climate. (2019).

90. Poloczanska, E. S., Burrows, M. T., Brown, C. J., Molinos, J. G., Halpern, B. S., Hoegh-Guldberg, O., Kappel, C. V., Moore, P. J., Richardson, A. J., Schoeman, D. S. & Sydeman, W. J. Responses of marine organisms to climate change across oceans. Frontiers in Marine Science 3, 1–21 (2016).

91. Silber, G. K., Lettrich, M. D., Thomas, P. O., Baker, J. D., Baumgartner, M., Becker, E. A., Boveng, P., Dick, D. M., Fiechter, J., Forcada, J., Forney, K. A., Griffis, R. B., Hare, J. A., Hobday, A. J., Howell, D., Laidre, K. L., Mantua, N., Quakenbush, L., Santora, J. A., Stafford, K. M., Spencer, P., Stock, C., Sydeman, W., Van Houtan, K. & Waples, R. S. Projecting marine mammal distribution in a changing climate. Frontiers in Marine Science 4, (2017).

92. Gulland, F., Baker, J. D., Howe, M., LaBrecque, E., Leach, L., Moore, S. E., Reeves, R. R. & Thomas, P. O. A review of climate change effects on marine mammals in United States waters: Past predictions, observed impacts, current research and conservation imperatives. Climate Change Ecology 3, 100054 (2022).

93. Sydeman, W. J., Poloczanska, E., Reed, T. E. & Thompson, S. A. Climate change and marine vertebrates. Science 350, 772–777 (2015).

94. Evans, P. G. H. & Bjørge, A. Impacts of climate change on marine mammals, MCCIP Science Review 2013. 134–148 (2013). doi:10.14465/2013.arc15.134-148

95. Bestley, S., Ropert-Coudert, Y., Bengtson Nash, S., Brooks, C. M., Cotté, C., Dewar, M., Friedlaender, A. S., Jackson, J. A., Labrousse, S., Lowther, A. D., McMahon, C. R., Phillips, R. A., Pistorius, P., Puskic, P. S., Reis, A. O. de A., Reisinger, R. R., Santos, M., Tarszisz, E., Tixier, P., Trathan, P. N., Wege, M. & Wienecke, B. Marine Ecosystem Assessment for the Southern Ocean: Birds and Marine Mammals in a Changing Climate. Frontiers in Ecology and Evolution 8, (2020).

96. Laidre, K. L., Stern, H., Kovacs, K. M., Lowry, L., Moore, S. E., Regehr, E. V., Ferguson, S. H., Wiig, Ø., Boveng, P., Angliss, R. P., Born, E. W., Litovka, D., Quakenbush, L., Lydersen, C., Vongraven, D. & Ugarte, F. Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. Conserv. Biol. 29, 724–737 (2015).

97. Laidre, K. L. & Heide-Jørgensen, M. P. Arctic sea ice trends and narwhal vulnerability. Biol. Conserv. 121, 509–517 (2005).

98. Heide-Jørgensen, M. P., Laidre, K. L., Borchers, D., Marques, T. A., Stern, H. & Simon, M. The effect of sea-ice loss on beluga whales (Delphinapterus leucas) in West Greenland. Polar Res. 29, 198–208 (2010).

99. Ferguson, S. H., Dueck, L., Loseto, L. L. & Luque, S. P. Bowhead whale *Balaena mysticetus* seasonal selection of sea ice. Mar. Ecol. Prog. Ser. 411, 285–297 (2010).

100. Atkinson, A., Hill, S. L., Pakhomov, E. A., Siegel, V., Reiss, C. S., Loeb, V. J., Steinberg, D. K., Schmidt, K., Tarling, G. A., Gerrish, L. & Sailley, S. F. Krill (*Euphausia superba*) distribution contracts southward during rapid regional warming. Nat. Clim. Chang. 9, (2019).

101. Tulloch, V. J. D., Richardson, A. J., Matear, R. & Brown, C. Future recovery of baleen whales is imperiled by climate change. Glob. Chang. Biol. 1263–1281 (2019). doi:10.1111/gcb.14573

102. Seyboth, E., Félix, F., Lea, M.-A., Dalla Rosa, L., Watters, G. M., Reid, K. & Secchi, E. R. Influence of krill (*Euphausia superba*) availability on humpback whale (*Megaptera novaeangliae*) reproductive rate. Mar. Mamm. Sci. 37, 1498–1506 (2021).

103. Risch, D., Norris, T., Curnock, M. & Friedlaender, A. Common and Antarctic Minke Whales: Conservation Status and Future Research Directions. Frontiers in Marine Science 6, 1–14 (2019).

104. Simmonds, M. P. in Marine Mammal Ecotoxicology (eds. Fossi, M. C. & Panti, C.) 459–470 (Academic Press, 2018). doi:10.1016/B978-0-12-812144-3.00017-6

105. IWC. Bycatch. International Whaling Commission (2021). at <***https://iwc.int/bycatch***>

106. Course, G. P., Pierre, J. & Howell, B. K. What's in the Net? Using camera technology to monitor, and support mitigation of, wildlife bycatch in fisheries. (WWF, 2020).

107. WWF. Stop Ghost Gear the Most Deadly Form of Marine Plastic Debris. 64 (WWF, 2020). at <***https://www.worldwildlife.org/publications/stop-ghost-gear-the-most-deadly-form-of-marine-plastic-debris***>

108. Macfadyen, G., Huntington, T. & Cappell, R. Abandoned, lost or otherwise discarded fishing gear. 523, 115 p. (2009).

109. Butterworth, A. A review of the welfare impact on pinnipeds of plastic marine debris. Front. Mar. Sci. 3, (2016).

110. Richardson, K., Hardesty, B. D. & Wilcox, C. Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis. Fish Fish 20, 1218–1231 (2019).

111. Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier, A., Noble, K., Debeljak, P., Maral, H., Schoeneich-Argent, R., Brambini, R. & Reisser, J. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Sci. Rep. 8, 1–15 (2018).

112. Stelfox, M., Hudgins, J. & Sweet, M. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. Mar. Pollut. Bull. 111, 6–17 (2016).

113. Tournadre, J. Anthropogenic pressure on the open ocean: The growth. Geophys. Res. Lett. 41, 7924–7932 (2014).

114. Sardain, A., Sardain, E. & Leung, B. Global forecasts of shipping traffic and biological invasions to 2050. Nature Sustainability 2, 274–282 (2019).

115. Lancaster, M., Agarkova, E., Albertini, A., Alidina, H., Akkaya Baş, A., Cosandey-Godin, A., Dumbrille, A., Houtman, N., Jacob, T., Johnson, C., Montecinos, Y., Nystrom, S., Smith, J. & Woo, D. Shipping and underwater noise – a growing risk to marine life worldwide. (WWF, 2021).

116. Erbe, C., Marley, S. A., Schoeman, R. P., Smith, J. N., Trigg, L. E. & Embling, C. B. The Effects of Ship Noise on Marine Mammals—A Review. Frontiers in Marine Science 6, (2019).

117. Minton, G., Folegot, T., Lancaster, M., Cosandey-Godin, A., Ushio, M. & Jacob, T. Shipping and Cetaceans: a Review of Impacts and Mitigation Options for Policymakers and Other Stakeholders. (WWF-Canada and WWF Protecting Whales & Dolphins Initiative, 2021).

118. Peel, D., Smith, J. N. & Childerhouse, S. Vessel strike of whales in Australia: The challenges of analysis of historical incident data. Frontiers in Marine Science 5, 1–14 (2018).

119. Reijnders, P. J. H., Borrell, A., Van Franeker, J. A. & Aguilar, A. in (eds. Würsig, B., Thewissen, J. G. M. & Kovacs, K. M. B. T.-. E. of M. M. (third E.) 746–753 (Academic Press, 2018). doi:10.1016/B978-0-12-804327-1.00202-8

120. Bengtson Nash, S. M. in Marine Mammal Ecotoxicology - Impacts of Multiple Stressors on Population Health (eds. Fossi, M. C. & Panti, C. B. T.-. M. M. E.) 381–400 (Academic Press, 2018). doi:10.1016/B978-0-12-812144-3.00014-0

121. Desforges, J.-P., Sonne, C., Dietz, R. & Letcher, R. in Marine Mammal Ecotoxicology - Impacts of Multiple Stressors on Population Health (eds. Fossi, M. C. & Panti, C. B. T.-. M. M. E.) 321–343 (Academic Press, 2018). doi:10.1016/B978-0-12-812144-3.00012-7

122. Ross, P. S., Ellis, G. M., Ikonomou, M. G., Barrett-Lennard, L. G. & Addison, R. F. High PCB Concentrations in Free-Ranging Pacific Killer Whales, Orcinus orca: Effects of Age, Sex and Dietary Preference. Mar. Pollut. Bull. 40, 504–515 (2000).

123. Kühn, S., Bravo Rebolledo, E. L. & van Franeker, J. A. in Marine Anthropogenic Litter (eds. Bergmann, M., Gutow, L. & Klages, M.) 75–116 (Springer International Publishing, 2015). doi:10.1007/978-3-319-16510-3_4

124. de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C. & Cañadas, A. As main meal for sperm whales: Plastics debris. Mar. Pollut. Bull. 69, 206–214 (2013).

125. Evans, K. & Hindell, M. A. The diet of sperm whales (*Physeter macrocephalus*)) in southern Australian waters. ICES J. Mar. Sci. 61, 1313–1329 (2004).

126. Baulch, S. & Perry, C. Evaluating the impacts of marine debris on cetaceans. Mar. Pollut. Bull. 80, 210–221 (2014).

127. Denuncio, P., Bastida, R., Dassis, M., Giardino, G., Gerpe, M. & Rodríguez, D. Plastic ingestion in Franciscana dolphins, Pontoporia blainvillei (Gervais and d'Orbigny, 1844), from Argentina. Mar. Pollut. Bull. 62, 1836–1841 (2011).

128. Bravo Rebolledo, E. L., Van Franeker, J. A., Jansen, O. E. & Brasseur, S. M. J. M. Plastic ingestion by harbour seals (*Phoca vitulina*) in The Netherlands. Mar. Pollut. Bull. 67, 200–202 (2013).

129. Lusher, A. L., McHugh, M. & Thompson, R. C. Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Mar. Pollut. Bull. 67, 94–99 (2013).

130. Besseling, E., Foekema, E. M., Van Franeker, J. A., Leopold, M. F., Kühn, S., Bravo Rebolledo, E. L., Heße, E., Mielke, L., IJzer, J., Kamminga, P. & Koelmans, A. A. Microplastic in a macro filter feeder: Humpback whale *Megaptera novaeangliae*. Mar. Pollut. Bull. 95, 248–252 (2015).

131. Werth, A. J., Blakeney, S. M. & Cothren, A. I. Oil adsorption does not structurally or functionally alter whale baleen. Royal Society Open Science 6, (2019).

132. Rochman, C. M. in Marine Anthropogenic Litter (eds. Bergmann, M., Gutow, L. & Klages, M.) 117–140 (Springer International Publishing, 2015). doi:10.1007/978-3-319-16510-3_5

133. Koelmans, A. A. in Marine Anthropogenic Litter (eds. Bergmann, M., Gutow, L. & Klages, M.) 309–324 (Springer International Publishing, 2015). doi:10.1007/978-3-319-16510-3_11

134. Shannon, G., McKenna, M. F., Angeloni, L. M., Crooks, K. R., Fristrup, K. M., Brown, E., Warner, K. A., Nelson, M. D., White, C., Briggs, J., McFarland, S. & Wittemyer, G. A synthesis of two decades of research documenting the effects of noise on wildlife. Biol. Rev. Camb. Philos. Soc. 91, 982–1005 (2016).

135. Hildebrand, J. Sources of Anthropogenic Sound in the Marine Environment. in (2004). at <***https://www.mmc.gov/wp-content/uploads/hildebrand.pdf***>

136. Veirs, S., Veirs, V. & Wood, J. D. Ship noise extends to frequencies used for echolocation by endangered killer whales. PeerJ 4, e1657 (2016).

137. Cox, T. M., Ragen, T. J., Read, A. J., Vos, E., Baird, R. W., Balcomb, K., Barlow, J., Caldwell, J., Cranford, T. & Crum, L. Understanding the impacts of anthropogenic sound on beaked whales. (Space and Naval Warfare Systems Center San Diego Ca, 2006).

138. McCauley, R. D., Day, R. D., Swadling, K. M., Fitzgibbon, Q. P., Watson, R. A. & Semmens, J. M. Widely used marine seismic survey air gun operations negatively impact zooplankton. Nature Ecology & Evolution 1, 195 (2017).

139. Peng, C., Zhao, X. & Liu, G. Noise in the Sea and Its Impacts on Marine Organisms. International Journal of Environmental Research and Public Health 12, Preprint at ***https://doi.org/10.3390/ijerph121012304*** (2015)

140. Thomson, P. G., Pillans, R., Jaine, F. R. A., Harcourt, R. G., Taylor, M. D., Pattiaratchi, C. B. & McLean, D. L. Acoustic Telemetry Around Western Australia's Oil and Gas Infrastructure Helps Detect the Presence of an Elusive and Endangered Migratory Giant. Frontiers in Marine Science 8, 1–9 (2021).

141. Deep Sea Conservation Coalition. The Growing Movement for a Moratorium on Deep-Sea Mining. Deep Sea Conservation Coalition (2022). at <***http://www.savethehighseas.org/momentum-for-a-moratorium/***>

142. Cuyvers, L., Berry, W., Gjerde, K., Thiele, T., Wilhem, C. Deep seabed mining: a rising environmental challenge. (IUCN and Gallifrey Foundation, 2018).

143. Huntington, H. P., Danielson, S. L., Wiese, F. K., Baker, M., Boveng, P., Citta, J. J., De Robertis, A., Dickson, D. M. S., Farley, E., George, J. C., Iken, K., Kimmel, D. G., Kuletz, K., Ladd, C., Levine, R., Quakenbush, L., Stabeno, P., Stafford, K. M., Stockwell, D. & Wilson, C. Evidence suggests potential transformation of the Pacific Arctic ecosystem is underway. Nat. Clim. Chang. 10, 342–348 (2020).

144. Swartz, S. L., Taylor, B. L. & Rugh, D. J. Gray whale *Eschrichtius robustus* population and stock identity. Mamm. Rev. 36, 66–84 (2006).

145. Smith, M. A., Goldman, M. S., Knight, E. J. & Warrenchuk, J. J. Ecological Atlas of the Bering, Chukchi, and Beaufort Seas. (2017).

146. Hovelsrud, G. K., McKenna, M. & Huntington, H. P. MARINE MAMMAL HARVESTS AND OTHER INTERACTIONS WITH HUMANS. Ecol. Appl. 18, S135–S147 (2008).

147. Kaufman, D. S., Schneider, D. P., McKay, N. P., Ammann, C. M., Bradley, R. S., Briffa, K. R., Miller, G. H., Otto-Bliesner, B. L., Overpeck, J. T. & Vinther, B. M. Recent Warming Reverses Long-Term Arctic Cooling. Science 325, 1236 LP–1239 (2009).

148. Guggenheim Partners. Guggenheim Partners Endorses World Economic Forum's Arctic Investment Protocol. Guggenheim Partners (2016). at <***https://www.guggenheimpartners.com/firm/news/guggenheim-partners-endorses-world-economic-forums***>

149. Stafford, K. M. Increasing detections of killer whales (Orcinus orca), in the Pacific Arctic. Mar. Mamm. Sci. 35, 696–706 (2019).

150. Stroeve, J. C., Serreze, M. C., Holland, M. M., Kay, J. E., Malanik, J. & Barrett, A. P. The Arctic's rapidly shrinking sea ice cover: a research synthesis. Clim. Change 110, 1005–1027 (2012).

151. Hauser, D. D. W., Laidre, K. L., Stafford, K. M., Stern, H. L., Suydam, R. S. & Richard, P. R. Decadal shifts in autumn migration timing by Pacific Arctic beluga whales are related to delayed annual sea ice formation. Glob. Chang. Biol. 23, 2206–2217 (2017).

152. National Oceanic and Atmospheric Administration. 2018–2021 Ice Seal Unusual Mortality Event in Alaska. NOAA Fisheries (2021). at <***https://www.fisheries.noaa.gov/alaska/marine-life-distress/2018-2021-ice-seal-unusual-mortality-event-alaska***>

153. Hiatt, T., Dalton, M., Felthoven, R., Fissel, B., Garber-Yonts, B., Haynie, A., Kasperski, S., Lew, D., Package, C., Sepez, J. & Seung, C. Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands area: Economic status of the groundfish fisheries off Alaska. (N.P.F.M. Council, Anchorage, Alaska., 2011). at <***https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands#2018***>

154. Rosen, Y. Russia is poised to open the first-ever commercial pollock fishery in Chukchi Sea. Arctic Today (2020).

155. U.S. Committee on the Marine Transportation System. A Ten-Year Projection of Maritime Activity in the U.S. Arctic Region, 2020-2030. 118 (2019).

156. WWF. Safety at the Helm: A Plan for Smart Shipping through the Bering Strait. (2020). at <***https://www.worldwildlife.org/publications/safety-at-the-helm-a-plan-for-smart-shipping-through-the-bering-strait***>

157. Heaney, K. Underwater noise pollution from shipping in the Arctic: a report to PAME. (2021).

158. Palacios, D. M., Irvine, L. M., Lagerquist, B. A., Fahlbusch, J. A., Calambokidis, J., Tomkiewicz, S. M. & Mate, B. R. A satellite-linked tag for the long-term monitoring of diving behavior in large whales. Anim Biotelemetry 10, 1–17 (2022).

159. Blount, D., Gero, S., Van Oast, J., Parham, J., Kingen, C., Scheiner, B., Stere, T., Fisher, M., Minton, G., Khan, C., Dulau, V., Thompson, J., Moskvyak, O., Berger-Wolf, T., Stewart, C. V., Holmberg, J. & Levenson, J. J. Flukebook: an open-source AI platform for cetacean photo identification. Mamm. Biol. (2022). doi:10.1007/s42991-021-00221-3

160. Huntington, H. P., Suydam, R. S. & Rosenberg, D. H. Traditional knowledge and satellite tracking as complementary approaches to ecological understanding. Environ. Conserv. 31, 177–180 (2004).

161. Mymrin, N. I., The Communities of Novoe Chaplino Uelen and Yanrakinnot, S. & Huntington, H. P. Traditional Knowledge of the Ecology of Beluga Whales (Delphinapterus leucas) in the Northern Bering Sea, Chukotka, Russia. Arctic 52, 62–70 (1999).

162. Calambokidis, J., Falcone, E. A., Quinn, T. J., Burdin, A. M., Clapham, P. J., Ford, J. K. B., Gabriele, C. M., Leduc, R., Mattila, D., Rojas-Bracho, L., Straley, J. M., Taylor, B. L., Urbán, J., Weller, D., Witteveen, B. H., Yamaguchi, M., Bendlin, A., Camacho, D., Flynn, K., Havron, A., Huggins, J., Maloney, N., Barlow, J. & Wade, P. R. SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific. Final report for Contract AB133F-03-RP-00078. (Cascadia Research, 2008).

163. Darling, J. Humpbacks: unveiling the mysteries. (Granville Island Publishing Ltd., 2009).

164. Palacios, D. M., Mate, B. R., Baker, C. S., Lagerquist, B. A., Irvine, L. M., Follett, T., Steel, D. & Hayslip., C. E. Humpback Whale Tagging in Support of Marine Mammal Monitoring Across Multiple Navy Training Areas in the Pacific Ocean: Final Report for the Hawaiian Breeding Area in Spring 2019, Including Historical Data from Previous Tagging Efforts. Prepared for Comma. 122 (2020).

165. Silber, G. K., Weller, D. W., Reeves, R. R., Adams, J. D. & Moore, T. J. Co-occurrence of gray whales and vessel traffic in the North Pacific Ocean. Endanger. Species Res. 44, 177–201 (2021).

166. Howell, E. A., Bograd, S. J., Morishige, C., Seki, M. P. & Polovina, J. J. On North Pacific circulation and associated marine debris concentration. Mar. Pollut. Bull. 65, 16–22 (2012).

167. Pichel, W. G., Churnside, J. H., Veenstra, T. S., Foley, D. G., Friedman, K. S., Brainard, R. E., Nicoll, J. B., Zheng, Q. & Clemente-Colón, P. Marine debris collects within the North Pacific Subtropical Convergence Zone. Mar. Pollut. Bull. 54, 1207–1211 (2007).

168. Barlow, J., Calambokidis, J., Falcone, E. A., Baker, C. S., Burdin, A. M., Clapham, P. J., Ford, J. K. B., Gabriele, C. M., LeDuc, R., Mattila, D. K., Quinn, T. J., II, Rojas-Bracho, L., Straley, J. M., Taylor, B. L., Urbán R., J., Wade, P., Weller, D., Witteveen, B. H. & Yamaguchi, M. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Mar. Mamm. Sci. 27, 793–818 (2011).

169. Cartwright, R., Venema, A., Hernandez, V., Wyels, C., Cesere, J. & Cesere, D. Fluctuating reproductive rates in Hawaii's humpback whales, *Megaptera novaeangliae*, reflect recent climate anomalies in the North Pacific. Royal Society Open Science 6, 181463 (2019).

170. Frankel, A. S., Gabriele, C. M., Yin, S. & Rickards, S. H. Humpback whale abundance in Hawai'i: Temporal trends and response to climatic drivers. Mar. Mamm. Sci. n/a, (2021).

171. Kugler, A., Lammers, M. O., Zang, E. J., Kaplan, M. B. & Aran Mooney, T. Fluctuations in Hawaii'S Humpback Whale *Megaptera Novaeangliae* Population Inferred from Male Song Chorusing Off Maui. Endanger. Species Res. 43, 421–434 (2020).

172. Wray, J. & Keen, E. M. Calving rate decline in humpback whales (*Megaptera novaeangliae*) of northern British Columbia, Canada. Mar. Mamm. Sci. 36, 709–720 (2020).

173. Johnson, C. Whales and the plastics problem. World Wildlife Fund (2021). at <***https://www.worldwildlife.org/stories/whales-and-the-plastics-problem***>

174. Carretta, J. V., Forney, K. A., Oleson, E. M., Weller, D. W., Lang, A. R., Baker, J., Muto, M. M., Hanson, B., Orr, A. J., Huber, H., Lowry, M. S., Barlow, J., Moore, J. E., Lynch, D., Carswell, L. & Brownell, R. L., Jr. U.S. Pacific marine mammal stock assessments: 2016. NOAA technical memorandum. NOAA-TM-NMFS-SWFSC-617. (2019). doi:10.25923/x17q-2p43

175. Abrahms, B., Hazen, E. L., Aikens, E. O., Savoca, M. S., Goldbogen, J. A., Bograd, S. J., Jacox, M. G., Irvine, L. M., Palacios, D. M. & Mate, B. R. Memory and resource tracking drive blue whale migrations. Proc. Natl. Acad. Sci. U. S. A. 116, 5582–5587 (2019).

176. Burtenshaw, J. C., Oleson, E. M., Hildebrand, J. A., McDonald, M. A., Andrew, R. K., Howe, B. M. & Mercer, J. A. Acoustic and satellite remote sensing of blue whale seasonality and habitat in the Northeast Pacific. Deep Sea Res. Part 2 Top. Stud. Oceanogr. 51, 967–986 (2004).

177. Reilly, S. B. & Thayer, V. G. Blue whale (*Balaenoptera Musculus*) distribution in the eastern tropical Pacific. Mar. Mamm. Sci. 6, 265–277 (1990).

178. Abrahms, B., Welch, H., Brodie, S., Jacox, M. G., Becker, E. A., Bograd, S. J., Irvine, L. M., Palacios, D. M., Mate, B. R. & Hazen, E. L. Dynamic ensemble models to predict distributions and anthropogenic risk exposure for highly mobile species. Diversity and Distributions 25, 1182–1193 (2019).

179. Blondin, H., Abrahms, B., Crowder, L. B. & Hazen, E. L. Combining high temporal resolution whale distribution and vessel tracking data improves estimates of ship strike risk. Biol. Conserv. 250, 108757 (2020).

180. Hazen, E. L., Palacios, D. M., Forney, K. A., Howell, E. A., Becker, E., Hoover, A. L., Irvine, L., DeAngelis, M., Bograd, S. J., Mate, B. R. & Bailey, H. WhaleWatch: a dynamic management tool for predicting blue whale density in the California Current. J. Appl. Ecol. 54, 1415–1428 (2017).

181. Irvine, L. M., Mate, B. R., Winsor, M. H., Palacios, D. M., Bograd, S. J., Costa, D. P. & Bailey, H. Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. PLoS One 9, (2014).

182. Redfern, J. V., McKenna, M. F., Moore, T. J., Calambokidis, J., DeAngelis, M. L., Becker, E. A., Barlow, J., Forney, K. A., Fieldler, P. C. & Chivers, S. J. Assessing the Risk of Ships Striking Large Whales in Marine Spatial Planning. Conserv. Biol. 27, 292–302 (2013).

183. Cotton Rockwood, R., Calambokidis, J. & Jahncke, J. Correction: High mortality of blue, humpback and fin whales from modeling of vessel collisions on the U.S. West Coast suggests population impacts and insufficient protection (PLoS ONE (2017) 12:8 (e0183052) DOI: 10.1371/journal.pone.0183052). PLoS One 13, 1–24 (2018).

184. Thomas, P. O., Reeves, R. R., Brownell, R. L. & Brownell, R. L., Jr. Status of the world's baleen whales. Mar. Mamm. Sci. 32, 682–734 (2016).

185. Rockwood, R. C., Adams, J., Silber, G. & Jahncke, J. Estimating effectiveness of speed reduction measures for decreasing whale-strike mortality in a high-risk region. Endanger. Species Res. 43, 145–166 (2020).

186. Szesciorka, A. R., Allen, A. N., Calambokidis, J., Fahlbusch, J., Mckenna, M. F., Southall, B., Smith, J. N. & Williamson, M. J. A Case Study of a Near Vessel Strike of a Blue Whale : Perceptual Cues and Fine-Scale Aspects of Behavioral Avoidance. 6, 1–10 (2019).

187. Southall, B. L., DeRuiter, S. L., Friedlaender, A., Stimpert, A. K., Goldbogen, J. A., Hazen, E., Casey, C., Fregosi, S., Cade, D. E., Allen, A. N., Harris, C. M., Schorr, G., Moretti, D., Guan, S. & Calambokidis, J. Behavioral responses of individual blue whales (*Balaenoptera musculus*) to mid-frequency military sonar. J. Exp. Biol. 222, (2019).

188. Pirotta, E., Booth, C. G., Cade, D. E., Calambokidis, J., Costa, D. P., Fahlbusch, J. A., Friedlaender, A. S., Goldbogen, J. A., Harwood, J., Hazen, E. L., New, L. & Southall, B. L. Context-dependent variability in the predicted daily energetic costs of disturbance for blue whales. Conservation Physiology 9, 1–15 (2021).

189. Wachtendonk, R., Calambokidis, J. & Flynn, K. Blue whale body condition assessed over a 14-year period in the NE Pacific: Annual variation and connection to measures of ocean productivity. Front. Mar. Sci. 9, (2022).

190. Noaa. 2019-2021 Gray Whale Unusual Mortality Event along the West Coast and Alaska. NOAA Fisheries (2021). at <***https://www.fisheries.noaa.gov/national/marine-life-distress/2019-2021-gray-whale-unusual-mortality-event-along-west-coast-and***>

191. Christiansen, F., Rodríguez-González, F., Martínez-Aguilar, S., Urbán, J., Swartz, S., Warick, H., Vivier, F. & Bejder, L. Poor body condition associated with an unusual mortality event in gray whales. Mar. Ecol. Prog. Ser. 658, 237–252 (2021).

192. Stewart, J. D. & Weller, D. W. NOAA Technical Memorandum: NMFS ABUNDANCE OF EASTERN NORTH PACIFIC GRAY WHALES 2019-2020. (2021).

193. Swartz, S. Annual gray whale research report for 2021. 1–14 (Laguna San Ignacio Ecosystem Science Program., 2021). at <***https://www.sanignaciograywhales.org/research/publications***>

194. Hausner, A., Samhouri, J. F., Hazen, E. L., Delgerjargal, D. & Abrahms, B. Dynamic strategies offer potential to reduce lethal ship collisions with large whales under changing climate conditions. Mar. Policy 130, 104565 (2021).

195. Myers, H. J., Moore, M. J., Baumgartner, M. F., Brillant, S. W., Katona, S. K., Knowlton, A. R., Morissette, L., Pettis, H. M., Shester, G. & Werner, T. B. Ropeless fishing to prevent large whale entanglements: Ropeless Consortium report. Mar. Policy 107, 103587 (2019).

196. Feist, B. E., Samhouri, J. F., Forney, K. A. & Saez, L. E. Footprints of fixed - gear fisheries in relation to rising whale entanglements on the U.S. West Coast. Fish. Manag. Ecol. 28, 283–294 (2021).

197. Bland, A. To Save the Whales, Crab Fishers Are Testing Ropeless Gear. Hakai Magazine (2019). at <***https://hakaimagazine.com/news/to-save-the-whales-crab-fishers-are-testing-ropeless-gear/***>

198. Alkire, C. Decline in on-demand fishing gear costs with learning. Front. Mar. Sci. 9, (2022).

199. Woods Hole Oceanographic Institution. Ropeless Consortium Towards whales without rope entanglements. 2021

200. Dfo. What We Heard Report: Gear Innovation Summit. 2021

201. Baumgartner, M., Moore, M., Kraus, S., Knowlton, A. & Werner, T. Overcoming Development, Regulatory and Funding Challenges for Ropeless Fishing to Reduce Whale Entanglement in the U.S. and Canada. Ropeless Workshop Report 45 p. Preprint at ***https://www.ncbi.nlm.nih.gov/pubmed/25246403*** (2018)

202. Knowlton, A. R., Robbins, J., Landry, S., McKenna, H. A., Kraus, S. D. & Werner, T. B. Effects of fishing rope strength on the severity of large whale entanglements. Conserv. Biol. 30, 318–328 (2016).

203. NOAA. Taking of Marine Mammals Incidental to Commercial Fishing Operations; Atlantic Large Whale Take Reduction Plan Regulations. Federal Register 72:57104-57194. (NOAA, 2007).

204. NOAA. Draft ropeless roadmap: A strategy to develop on-demand fishing. NOAA (2022). at <***https://media.fisheries.noaa.gov/2022-07/RopelessRoadmapDRAFT-NEFSC.pdf***>

205. UNEP-WCMC. El Vizcaíno Biosphere Reserve. Protected Planet (2021). at <***https://www.protectedplanet.net/61409***>

206. Daley, J. Mexico Establishes Largest Marine Protected Area in North America. Smithsonian Magazine (2017). at <***https://www.smithsonianmag.com/smart-news/mexico-declares-north-americas-largest-marine-reserve-180967309/***>

207. UNEP-WCMC. Parque Nacional Cabo Pulmo. Protected Planet (2021). at <***https://www.protectedplanet.net/903127***>

208. UNEP-WCMC. Parque Nacional Bahía de Loreto. Protected Planet (2021). at <***https://www.protectedplanet.net/902309***>

209. UNEP-WCMC. Islas del Pacífico de la Península de Baja California. Protected Planet (2021). at <***https://www.protectedplanet.net/555624304***>

210. National Geographic. Islas Marías Biosphere Reserve Becomes Newest Fully Protected Marine Area in Mexico. National Geographic (2021). at <***https://blog.nationalgeographic.org/2021/08/26/islas-marias-biosphere-reserve-becomes-newest-fully-protected-marine-area-in-mexico/***>

211. UNEP-WCMC. Islas del Golfo de California. Protected Planet (2021). at <***https://www.protectedplanet.net/306810***>

212. Fraga, J. & Jesus, A. Coastal and marine protected areas in Mexico. SAMUDRA Monograph. 97 (ICSF, 2008).

213. Chávez, R. & De La Cueva, H. Sustentabilidad y regulación de la observación de ballenas en México. Revista Legislativa De Estudios Sociales Y De Opinión Pública 2, 231–262 (2009).

214. SEMARNAT. NOM-135 Semarnat-2004. Para la regulación de la capturapara investigación, transporte, exhibición, manejo y manutención. Preprint at (2004)

215. SEMARNAT. NOM-059-ECOL-2010. Protección ambiental a especies nativasde México de flora y fauna silvestres, bajo categorías de riesgo y especificaciones para su inclusión, exclusión o cambio. Preprint at (2010)

216. SEMARNAT. NOM-131-Semarnat-1998 Lineamientos y especificaciones para el desarrollo de actividades de observación de ballenas, relativas a su protección y la conservación de su hábitat. Preprint at (2000)

217. DOF. Acuerdo mediante el cual se expide el Protocolo de atención para varamiento de mamíferos marinos. Preprint at (2004)

218. Jefferson, T. A., Webber, M. A. & Pitman, R. L. Marine Mammals of the World, a comprehensive guide to their identification. 573 (Academic Press, 2008).

219. Acevedo, A. & Smultea, M. A. First records of humpback whales including calves at Golfo Dulce and Isla del Coco, Costa Rica, suggesting geographical overlap of northern and southern hemisphere populations. Mar. Mamm. Sci. 11, 554–560 (1995).

220. Palacios, D. M., Martins, C. C. A. & Olavarr'\ia, C. Aquatic mammal science in Latin America: a bibliometric analysis for the first eight years of the Latin American Journal of Aquatic Mammals (2002-2010). Lat. Am. J. Aquat. Mamm. 9, 42–64 (2011).

221. Rasmussen, K., Palacios, D. M., Calambokidis, J., Saborío, M. T., Dalla Rosa, L., Secchi, E. R., Steiger, G. H., Allen, J. M., Stone, G. S., Rosa, L. D., Secchi, E. R., Steiger, G. H., Allen, J. M. & Stone, G. S. Southern Hemisphere humpback whales wintering off Central America : insights from water temperature into the longest mammalian migration. Biol. Lett. 3, 302–305 (2007).

222. Fiedler, P. C., Redfern, J. V. & Ballance, L. T. in 1–37 (2017).

223. Global Fishing Watch. Analysis of the Southeast Pacific Distant Water Squid Fleet. (Global Fishing Watch, 2021).

224. Whitehead, H. Sperm Whale: *Physeter macrocephalus*. Encyclopedia of Marine Mammals (Second Edition) 8235, 1091–1097 (2009).

225. Kato, H. & Perrin, W. F. in Encyclopedia of Marine Mammals 158–163 (Elsevier, 2009). doi:10.1016/b978-0-12-373553-9.00042-0

226. Whitehead, H., McGill, B. & Worm, B. Diversity of deep-water cetaceans in relation to temperature: implications for ocean warming. Ecol. Lett. 11, 1198–1207 (2008).

227. Félix, F. & Guzmán, H. M. Satellite tracking and sighting data analyses of Southeast Pacific humpback whales (*Megaptera novaeangliae*): Is the migratory route coastal or oceanic? Aquat. Mamm. 40, 329–340 (2014).

228. Guzman, H. M. & Félix, F. Movements and habitat use by Southeast Pacific humpback whales (*Megaptera novaeangliae*) satellite tracked at two breeding sites. Aquat. Mamm. 43, (2017).

229. De Weerdt, J., Ramos, E. A. & Cheeseman, T. Northernmost records of Southern Hemisphere humpback whales (*Megaptera novaeangliae*) migrating from the Antarctic Peninsula to the Pacific coast of Nicaragua. Mar. Mamm. Sci. 1–7 (2020). doi:e02214. 10.1002/eap.2214

230. Modest, M., Irvine, L., Andrews-Goff, V., Gough, W., Johnston, D., Nowacek, D., Pallin, L., Read, A., Moore, R. T. & Friedlaender, A. First Description of Migratory Behavior of Humpback Whales From an Antarctic Feeding Ground to a Tropical Breeding Ground. Animal Biotelemetry (2021). doi:10.21203/rs.3.rs-224086/v1

231. Hucke-Gaete, R., Haro, D., Torres-Florez, J. P., Montecinos, Y., Viddi, F., Bedriñana-Romano, L., Nery, M. F. & Ruiz, J. A historical feeding ground for humpback whales in the eastern South Pacific revisited: the case of northern Patagonia, Chile. Aquat. Conserv. 23, 858–867 (2013).

232. Hucke-Gaete, R., Osman, L. P., Moreno, C. A., Findlay, K. P. & Ljungblad, D. K. Discovery of a blue whale feeding and nursing ground in southern Chile. Proceedings of the Royal Society of London. Series B: Biological Sciences 271, S170–S173 (2004).

233. Guzman, H. M., Gomez, C. G., Guevara, C. A. & Kleivane, L. Potential vessel collisions with Southern Hemisphere humpback whales wintering off Pacific Panama. Mar. Mamm. Sci. 29, 629–642 (2013).

234. Cates, K., DeMaster, D. P., Brownell, R. L., Jr, Silber, G., Gende, S., Leaper, R., Ritter, F. & Panigada, S. Strategic Plan to Mitigate the Impacts of Ship Strikes on Cetacean Populations: 2017-2020. IWC (2017). at <***https://www.researchgate.net/profile/Gregory-Silber-2/publication/332539367_Strategic_Plan_to_Mitigate_the_Impacts_of_Ship_Strikes_on_Cetacean_Populations_2017-2020/links/5cbada314585156cd7a4844f/Strategic-Plan-to-Mitigate-the-Impacts-of-Ship-Strikes-on-Cetacean-Populations-2017-2020.pdf***>

235. Rasmussen, K., Calambokidis, J. & Steiger, G. H. Distribution and migratory destinations of humpback whales off the Pacific coast of Central America during the boreal winters of 1996-2003. Mar. Mamm. Sci. 28, E267–E279 (2012).

236. Rasmussen, K. & Palacios, D. M. Highlights from a decade of humpback whale research in the gulf of Chiriqui, western Panama, 2002-2012. IWC Scientific Committee Publication No. SC/65a/SH04 (2013). at <***http://www.panacetacea.org/uploads/6/6/8/1/6681148/rasmussen_and_palacios_iwc_2013_sc_65a_sh04.pdf***>

237. Guzman, H. M., Hinojosa, N. & Kaiser, S. Ship ' s compliance with a traffic separation scheme and speed limit in the Gulf of Panama and implications for the risk to humpback whales. Mar. Policy 120, 104113 (2020).

238. Félix, F. & Van Waerebeek, K. Whale mortality from ship strikes in Ecuador and West Africa. Lat. Am. J. Aquat. Mamm. 4, 55–60 (2005).

239. Félix, F., Muñoz, M., Falcon, J., Botero, N. & Haase, B. Entanglement of humpback whales in artisanal fishing gear in ecuador. J. Cetacean Res. Manag. 285–290 (2011). doi:10.47536/jcrm.vi.308

240. Garcia-Cegarra, A. M., Villagra, D., Gallardo, D. I. & Pacheco, A. S. Statistical dependence for detecting whale - watching effects on humpback whales. J. Wildl. Manage. 83, 467–477 (2019).

241. Bedriñana-Romano, L., Hucke-Gaete, R., Viddi, F. A., Johnson, D., Zerbini, A. N., Morales, J., Mate, B. & Palacios, D. M. Defining priority areas for blue whale conservation and investigating overlap with vessel traffic in Chilean Patagonia, using a fast-fitting movement model. Sci. Rep. 11, 1–16 (2021).

242. Caruso, F., Hickmott, L., Warren, J. D., Segre, P., Chiang, G., Bahamonde, P., Español-Jiménez, S., Songhai, L. I. & Bocconcelli, A. Diel differences in blue whale (*Balaenoptera musculus*) dive behavior increase nighttime risk of ship strikes in northern Chilean Patagonia. Integr. Zool. 594–611 (2020). doi:10.1111/1749-4877.12501

243. Guzman, H. M., Capella, J. J., Valladares, C., Gibbons, J. & Condit, R. Humpback whale movements in a narrow and heavily-used shipping passage, Chile. Mar. Policy 118, (2020).

244. Toro, F., Leichtle, J., Abarca, P., Aravena, P. & Pincheira, B. in American Journal Latin American Journal of Aquatic Mammals. 32–37 (2020).

245. Collyns, D. Latin American countries join reserves to create vast marine protected area. The Guardian (2021).

246. Government of Mexico. Se integra el Parque Nacional Revillagigedo a la Red de Áreas Marinas Protegidas del Corredor Marino del Pacífico Este Tropical (CMAR). Government of Mexico (2022). at <***https://www.gob.mx/conanp/articulos/se-integra-el-parque-nacional-revillagigedo-a-la-red-de-areas-marinas-protegidas-del-corredor-marino-del-pacifico-este-tropical-cmar***>

247. CMAR. Qué es el CMAR. CMAR (2022). at <***https://www.cmarpacifico.org/quienes-somos/que-es-el-cmar***>

248. Boteler, B., Wagner, D., Durussel, C., Stokes, E., Gaymer, C. F., Friedlander, A. M., Dunn, D. C., Vargas, F. P., Veliz, D. & Hazin, C. Borderless conservation: Integrating connectivity into high seas conservation efforts for the Salas y Gómez and Nazca ridges. Front. Mar. Sci. 9, (2022).

249. Félix, F., Rasmussen, K., Garita, F., Haase, B. & Simonis, A. Movements of humpback whales between Ecuador and Central America, wintering area of the Breeding Stock G. in SC/61/SH18 (International Whaling Commission, 2009). at <***https://www.researchgate.net/profile/Anne-Simonis/publication/228500708_Movements_of_humpback_whales_between_Ecuador_and_Central_America_wintering_area_of_the_Breeding_Stock_G/links/02bfe510fec9b0ae45000000/Movements-of-humpback-whales-between-Ecuador-and-Central-America-wintering-area-of-the-Breeding-Stock-G.pdf***>

250. Castro, C., Alcorta, B., Allen, J., Cáceres, C., Forestell, P., Kaufman, G., Mattila, D., Pacheco, A. S., Robbins, J., Santillan, L. & Others. Comparison of the humpback whale catalogues between Ecuador, Peru and American Samoa evidence of the enlargement of the breeding Stock G to Peru. in SC/63/SH19 (Scientific Committee of the International Whaling Commission, 2011). at <***https://www.academia.edu/download/55396436/Comparison_of_the_humpback_whale_catalog20171228-11696-b6ipwm.pdf***>

251. Ministerio del Ambiente, A. y. T. E.-E. Guillermo Lasso, President of Ecuador Opened the COP26 Summit Announcing a New Marine Reserve for the Galapagos Islands. PR Newswire (2021). at <***https://www.prnewswire.com/news-releases/guillermo-lasso-president-of-ecuador-opened-the-cop26-summit-announcing-a-new-marine-reserve-for-the-galapagos-islands-301413026.html***>

252. Jankowska, E., Pelc, R., Alvarez, J., Mehra, M. & Frischmann, C. J. Climate benefits from establishing marine protected areas targeted at blue carbon solutions. Proc. Natl. Acad. Sci. U. S. A. 119, e2121705119 (2022).

253. Sala, E., Mayorga, J., Bradley, D., Cabral, R. B., Atwood, T. B., Auber, A., Cheung, W., Costello, C., Ferretti, F., Friedlander, A. M., Gaines, S. D., Garilao, C., Goodell, W., Halpern, B. S., Hinson, A., Kaschner, K., Kesner-Reyes, K., Leprieur, F., McGowan, J., Morgan, L. E., Mouillot, D., Palacios-Abrantes, J., Possingham, H. P., Rechberger, K. D., Worm, B. & Lubchenco, J. Protecting the global ocean for biodiversity, food and climate. Nature 592, 397–402 (2021).

254. Reyes-Robles, J. Ballenas, delfines y otros cetaceos del Peru: Una fuente de informacion. (2009).

255. Cooke, J. G. *Eubalaena australis* (Chile-Peru subpopulation). The IUCN Red List of Threatened Species 2018 (2018).

256. García-Cegarra, A. M. & Pacheco, A. S. Collision risk areas between fin and humpback whales with large cargo vessels in Mejillones Bay (23°S), northern Chile. Mar. Policy 103, 182–186 (2019).

257. García-Godos, I. Revisión de las interacciones entre cetáceos y la pesquería marina peruana; perspectivas para la conservación de cetáceos en Perú. Memorias del Taller de Trabajo sobre el Impacto de las Actividades Antropogénicas en Mamíferos Marinos en el Pacífico Sudeste. 77–82 (2007).

258. J.C. Jeri H. Guzman A. Leslie. The last fluke of the trip: Preventing ship strike risk for humpback whales in Peru IWC SC/68A/HIM 09. in International Whaling Commission Scientific Committee 68A (2019). at <***https://archive.iwc.int/?r=12036***>

259. CBD. Eastern Tropical and Temperate Pacific Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs). Preprint at ***https://www.cbd.int/meetings/EBSA-ETTP-01*** (2012)

260. Germani, F. S. In Chile, Indigenous Management of Coastal Areas Improves Marine Conservation. Pew Charitable Trusts (2020). at <***https://www.pewtrusts.org/en/research-and-analysis/articles/2020/07/28/in-chile-indigenous-management-of-coastal-areas-improves-marine-conservation***>

261. O'Leary, B. C., Hoppit, G., Townley, A., Allen, H. L., McIntyre, C. J. & Roberts, C. M. Options for managing human threats to high seas biodiversity. Ocean Coast. Manage. 187, 105110 (2020).

262. Wright, G., Gjerde, K. M., Johnson, D. E., Finkelstein, A., Adelaide, M., Dunn, D. C., Rodriguez, M., Grehan, A., Ferreira, M. A., Dunn, D. C., Chaves, M. R. & Grehan, A. Marine spatial planning in areas beyond national jurisdiction. Mar. Policy 103384 (2019). doi:10.1016/j.marpol.2018.12.003

263. Cremers, K., Wright, G., Rochette, J., Gjerde, K. & Harden-Davies, H. A preliminary analysis of the draft high seas biodiversity treaty. Institute for Sustainable Development and International Relations Study (2020).

264. Hill, S. L., Cavanagh, R. D., Knowland, C. A., Grant, S. & Downie, R. Bridging the Krill Divide: Understanding Cross-Sector Objectives for Krill Fishing and Conservation. 37 (British Antarctic Survey, 2014).

265. Walpole, S. C., Prieto-Merino, D., Edwards, P., Cleland, J., Stevens, G. & Roberts, I. The weight of nations: an estimation of adult human biomass. BMC Public Health 12, 439 (2012).

266. Atkinson, A., Angus, A., Hill, S. L., Manuel, B., Pakhomov, E. A., David, R., Katrin, S., Simpson, S. J. & Christian, R. Sardine cycles, krill declines, and locust plagues: revisiting "wasp-waist" food webs. Trends Ecol. Evol. 29, 309–316 (2014).

267. Friedlaender, A. S., Tyson, R. B., Stimpert, A. K., Read, A. J. & Nowacek, D. P. Extreme diel variation in the feeding behavior of humpback whales along the western Antarctic Peninsula during autumn. Mar. Ecol. Prog. Ser. 494, 281–289 (2013).

268. Friedlaender, A. S., Johnston, D. W., Tyson, R. B., Kaltenberg, A., Goldbogen, J. A., Stimpert, A. K., Curtice, C., Hazen, E. L., Halpin, P. N., Read, A. J. & Nowacek, D. P. Multiple-stage decisions in a marine central-place forager. Royal Society Open Science 3, 160043 (2016).

269. Tyson, R. B., Friedlaender, A. S. & Nowacek, D. P. Does optimal foraging theory predict the foraging performance of a large air-breathing marine predator? Anim. Behav. 116, 223–235 (2016).

270. Ware, C., Friedlaender, A. S. & Nowacek, D. P. Shallow and deep lunge feeding of humpback whales in fjords of the West Antarctic Peninsula. Mar. Mamm. Sci. 27, 587–605 (2011).

271. Weinstein, B., Irvine, L. & Friedlaender, A. S. Capturing foraging and resting behavior using nested multivariate Markov models in an air-breathing marine vertebrate. Movement ecology (2018).

272. Johnston, D. W., Friedlaender, A. S., Read, A. J. & Nowacek, D. P. Initial density estimates of humpback whales *Megaptera novaeangliae* in the inshore waters of the western Antarctic Peninsula during the late autumn. Endanger. Species Res. 18, 63–71 (2012).

273. Nowacek, D. P., Friedlaender, A. S., Halpin, P. N., Hazen, E. L., Johnston, D. W., Read, A. J., Espinasse, B., Zhou, M. & Zhu, Y. Super-Aggregations of Krill and Humpback Whales in Wilhelmina Bay, Antarctic Peninsula. PLoS One 6, e19173 (2011).

274. Curtice, C., Johnston, D. W., Ducklow, H., Gales, N., Halpin, P. N. & Friedlaender, A. S. Modeling the spatial and temporal dynamics of foraging movements of humpback whales (*Megaptera novaeangliae*) in the Western Antarctic Peninsula. Movement ecology 3, 13 (2015).

275. Weinstein, B. G. & Friedlaender, A. S. Dynamic foraging of a top predator in a seasonal polar marine environment. Oecologia 185, 427–435 (2017).

276. Espinasse, B., Zhou, M., Zhu, Y., Hazen, E. L., Friedlaender, A. S., Nowacek, D. P., Chu, D. & Carlotti, F. Austral fall−winter transition of mesozooplankton assemblages and krill aggregations in an embayment west of the Antarctic Peninsula. Mar. Ecol. Prog. Ser. 452, 63–80 (2012).

277. Tulloch, V. J. D., Plagányi, É. E., Matear, R., Brown, C. J. & Richardson, A. J. Ecosystem modelling to quantify the impact of historical whaling on Southern Hemisphere baleen whales. Fish Fish 19, 117–137 (2018).

278. Turner, J., Barrand, N. E., Bracegirdle, T. J., Convey, P., Hodgson, D. a., Jarvis, M., Jenkins, A., Marshall, G., Meredith, M. P., Roscoe, H., Shanklin, J., French, J., Goosse, H., Guglielmin, M., Gutt, J., Jacobs, S., Kennicutt, M. C. I. I., Masson-Delmotte, V., Mayewski, P., Navarro, F., Robinson, S., Scambos, T., Sparrow, M., Summerhayes, C., Speer, K. & Klepikov, A. Antarctic climate change and the environment: an update. Polar Rec. 50, 1–23 (2014).

279. Veytia, D., Corney, S., Meiners, K. M., Kawaguchi, S., Murphy, E. J. & Bestley, S. Circumpolar projections of Antarctic krill growth potential. Nat. Clim. Chang. 10, 568–575 (2020).

280. Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., Pfeiffer, S., Scott, J. & Snape, I. Impacts of local human activities on the Antarctic environment. Antarct. Sci. 21, 3–33 (2009).

281. Weinstein, B. G., Double, M., Gales, N., Johnston, D. W. & Friedlaender, A. S. Identifying overlap between humpback whale foraging grounds and the Antarctic krill fi shery. Biol. Conserv. 210, 184–191 (2017).

282. CCAMLR. CCAMLR Fisheries Reports. Commission for the Conservation of Antarctic Marine Living Resources (2021). at <***http://fisheryreports.ccamlr.org/***>

283. Welsford, D., Walker, N., Favero, M., Krafft, B., Darby, C. & Parker, S. CCAMLR-IWC coordination: Incidents of whale bycatch in the Antarctic krill fishery SC/68D/HIM/04. International Whaling Commission Preprint at ***https://archive.iwc.int/pages/view.php?ref=19516&k=8e3f9fe77c*** (2022)

284. CCAMLR. Conservation Measure 91-04. General framework for the establishment of CCAMLR Marine Protected Areas. Preprint at ***http://archive.ccamlr.org/pu/E/e_pubs/cm/11-12/91-04.pdf*** (2011)

285. Constable, A. J., De LaMare, W. K., Agnew, D. J., Everson, I. & Miller, D. Managing fisheries to conserve the Antarctic marine ecosystem: Practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). ICES J. Mar. Sci. 57, 778–791 (2000).

286. Forcada, J., Trathan, P. N., Boveng, P. L., Boyd, I. L., Burns, J. M., Costa, D. P., Fedak, M., Rogers, T. L. & Southwell, C. J. Responses of Antarctic pack-ice seals to environmental change and increasing krill fishing. Biol. Conserv. (2012). doi:10.1016/j.biocon.2012.02.002

287. Trathan, P. N. & Hill, S. L. in Biology and ecology of Antarctic Krill 321–350 (Springer, 2016).

288. Trivelpiece, W. Z., Hinke, J. T., Miller, A. K., Reiss, C. S., Trivelpiece, S. G. & Watters, G. M. Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica. Proc. Natl. Acad. Sci. U. S. A. 108, 7625–7628 (2011).

289. Watters, G. M., Hinke, J. T. & Reiss, C. S. Long-term observations from Antarctica demonstrate that mismatched scales of fisheries management and predator-prey interaction lead to erroneous conclusions about precaution. Sci. Rep. 10, 1–9 (2020).

290. Santa Cruz, F., Ernst, B., Arata, J. A. & Parada, C. Spatial and temporal dynamics of the Antarctic krill fishery in fishing hotspots in the Bransfield Strait and South Shetland Islands. Fish. Res. 208, 157–166 (2018).

291. Johnson, C. Uncovering the lives of whales to better understand our oceans. WWF (2021). at <***https://wwfoceans.medium.com/uncovering-the-lives-of-whales-to-better-understand-our-oceans-2a3cfc9678e4***>

OUR MISSION IS TO CONSERVE NATURE AND REDUCE THE MOST PRESSING THREATS TO THE DIVERSITY OF LIFE ON EARTH.

Working to sustain the natural world for the benefit of people and wildlife.

together possible™

panda.org

For contact details and further information, visit the WWF Protecting Whales and Dolphins Initiative at: **WWFwhales.org**