UN environment programme

CMS

CONVENTION ON MIGRATORY SPECIES

UNEP/CMS/COP15/Inf.25.4.1b
04 December 2025
Original: English

15th MEETING OF THE CONFERENCE OF THE PARTIES
Campo Grande, Brazil, 23 to 29 March 2026
Agenda Item 25.4.1

REPORT ON THE IMPACTS OF CLIMATE CHANGE ON CETACEAN WELFARE AND CONSERVATION

(Prepared by the Secretariat)

Summary:

This document contains the *Report on the impacts of climate change on cetacean welfare and conservation* that was written in accordance with Decision 14.72 (b).

Report on the impacts of climate change on cetacean welfare and conservation

UKRI JNCC internship

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2025

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1 Background

1.1 Cetacean distribution and migration

Species distributions can be defined as the permanent or long-term geographic range where a species can be found, whereas migrations can be defined as seasonal or periodic movements from one area to another. The Convention on Migratory Species (CMS) defines migratory species as 'the entire population or any geographically separate part of the population of any species or lower taxon of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries' (*Convention on the Conservation of Migratory Species of Wild Animals, n.d.)*. Patterns of these distributions and migrations are shaped by a complex interplay of ecological, biological, and environmental factors (Learmonth *et al.,* 2006).

Cetaceans (whales, dolphins, and porpoises) are distributed throughout the world's oceans, and some are highly migratory. Cetacean distributions are primarily influenced by species' thermal limits and can be split into four groupings as defined by MacLeod (2009):

- **Cosmopolitan species:** occur in all water temperatures from ice-edge to tropical waters.
- **Cooler water-limited species:** occur from the ice-edges of polar waters to waters of a specific temperature range.
- **Cooler and warmer water-limited species:** limited to waters of intermediate temperature and do not cross the equator or extend into cooler waters.
- **Warmer water-limited species:** continuous cross-equatorial limits in at least one ocean that do not occur in cooler waters of the same ocean.

The migration of cetaceans is driven by reproductive and energy requirements (Dunn *et al.,* 2019; Learmonth *et al.,* 2006):

- **Baleen whales:** generally undertake long seasonal migrations between different habitats of tropical grounds in the winter and higher latitude grounds in summer.
- **Toothed whales:** usually undertake shorter range shifts displaying offshore and inshore movements, however, some species (e.g. sperm whales) may undertake long distance migrations.

1.2 Impacts of climate change on cetaceans

Climate change, primarily driven by greenhouse gas (GHG) emissions from human activities, has significantly altered global temperatures and ocean conditions (Calvin *et al.,* 2023). From the pre-industrial period (1850–1900) to recent years (2011–2020), global

surface temperatures have increased by 1.1°C, and projections suggest a further rise of at least 1.5°C is likely (Calvin *et al.,* 2023).

Ocean temperatures have increased by approximately 0.88°C, leading to widespread and cascading effects on the marine environment, such as decreases in sea-ice cover, rising sea levels, weakening of ocean thermohaline, changes in salinity, decreased pH (increased acidity), and increased frequency of extreme weather conditions (El Niño/North Atlantic Oscillation) (Calvin *et al.,* 2023, Learmonth *et al.,* 2006).

The impact of climate change is now considered to be one of the top ten threats to all marine mammals and changes in the marine environment are having both direct and indirect consequences for cetaceans worldwide (Lascelles *et al.,* 2014). Several key studies have attempted to categorise these impacts, providing useful frameworks for understanding the breadth of climate-related pressures on cetaceans (IWC, 2012; Alter *et al.,* 2010; Simmonds & Eliott, 2009; Learmonth *et al.,* 2006; Simmonds & Isaac, 2006). However, the impacts of climate change can be particularly difficult to classify because they involve numerous, complex relationships that are nonlinear (Simmonds & Isaac 2007). As a result, this report suggests collating the impacts of climate change on cetaceans into four broad categories *(Figure 1)*, designed to offer a clear and structured overview. It is important to note that Figure 1 provides a general overview and is not an exhaustive list of impacts.

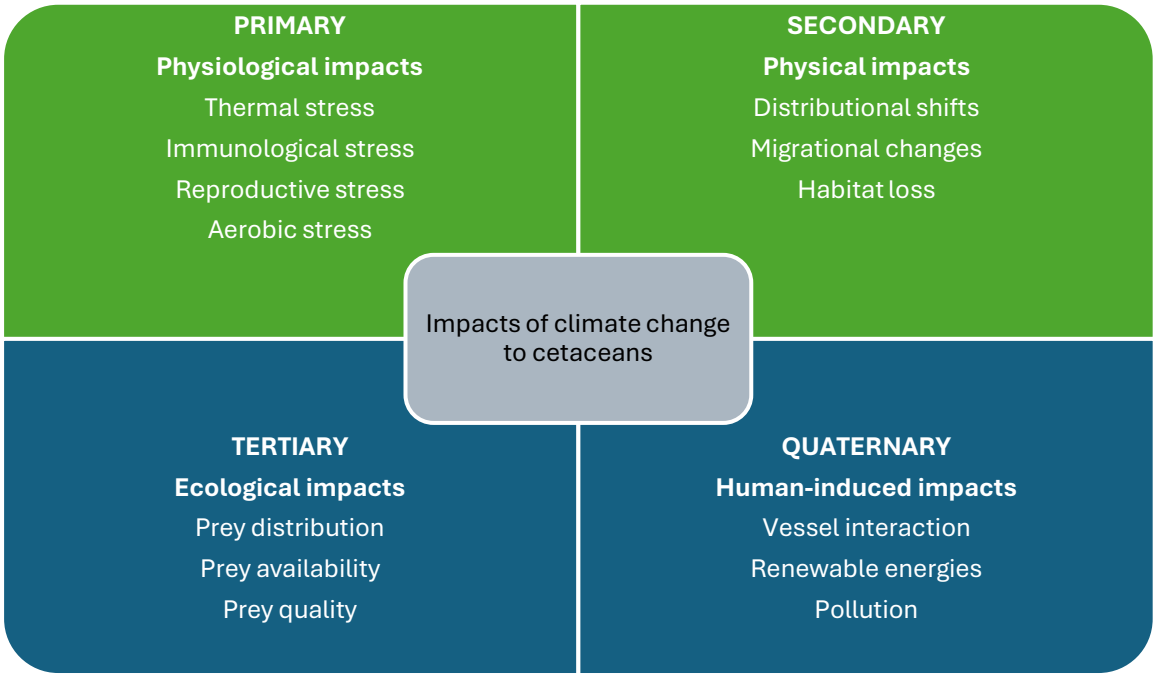

Figure 1: Direct (green) and indirect (blue) impacts of climate change on cetaceans.

Climate change impacts on cetacean species were first discussed in 1996 at The International Whaling Commission's (IWC) Scientific Committee climate change workshop (IWC, 2010). At that point in time, the knowledge (e.g., species biology and behaviours, prey dynamics) and modelling capabilities needed to confidently predict the impacts of climate change on cetaceans were lacking (IWC, 2010). Since then, growing evidence of climate-related impacts on the majority of cetacean species has become evident.

A series of IWC workshops (2012 – 2022), several key literature reviews, and a climate change workshop have examined and discussed both observed and predicted impacts of climate change on cetacean species (IWC, 2010, 2012, 2014, 2021; Learmonth *et al*. 2006; Simmonds & Isaac, 2007; MacLeod, 2009; Simmonds & Eliott, 2009; Kaschner *et al.,* 2011; van Weelden *et al.,* 2021; Martay *et al.,* 2023; *Report of the Migratory Species and Climate Change Expert Workshop*, 2025). Collectively, these findings highlight a range of direct (primary and secondary) and indirect (tertiary and quaternary) impacts. Direct impacts include widespread shifts in cetacean distribution (poleward movements), altered migration (spatially and temporally), and reductions in suitable habitat (especially in polar regions and restricted water basins) (Learmonth *et al.,* 2006; MacLeod, 2009; Kaschner *et al.,* 2011; IWC, 2012; van Weelden *et al.,* 2021). Indirect impacts include changes in prey availability and distribution, elevated predation and competition pressure, increased exposure to pollutants and harmful algal blooms, and intensified pressure from human activities (IWC, 2014).

However, certain species and regions are expected to be disproportionately affected by climate change due to species current conservation status, ecological characteristics, and geographic constraints. Resident Arctic species such as belugas, narwhals, and bowhead whales are evidently among the most at immediate risk from climatic changes due to their strong dependence on sea ice, limited habitat flexibility, and increasing pressures from human activities in newly accessible Arctic waters (IWC, 2014; van Weelden *et al.,* 2021). Species such as river dolphins, harbour porpoises, vaquitas, *Lagenorhynchus*, and *Cephalorhynchus,* which live in enclosed areas within river basins, the Mediterranean Sea, Black Sea, and Baltic Sea, are also at elevated risk due to restricted distributions, limited ability to shift ranges, thermal stress, and additional pressures from cumulative human impacts (Report of the Migratory Species and Climate Change Expert Workshop, 2025; IWC, 2014; Kaschner *et al.,* 2011; MacLeod, 2009; Learmonth *et al.,* 2006). Many baleen whales are initiating migration earlier or returning later in response to climate change, with some species also altering their routes. These changes can reduce body condition, leading to increased mortality rates and reduced reproduction rates (Tulloch *et al.,* 2021). Critically endangered species like the North Atlantic right whale are particularly vulnerable (Tulloch *et al.,* 2025). In contrast, generalist species with broad ecological ranges, such as common bottlenose dolphins, striped dolphins, humpback whales, and sperm whales, may demonstrate greater

resilience and adaptability through range shifts, prey switching, and flexible habitat use (MacLeod, 2009; van Weelden *et al.,* 2021).

1.3 Impacts of climate change on cetacean welfare

Whilst research demonstrates climate change has significant adverse effects on cetacean ecology, little consideration has been given to the **welfare** of cetaceans – which refers to the overall health and well-being that encompasses both physical and psychological aspects (Simmonds, 2017).

Cetacean welfare can be classified and assessed through five categories of: nutrition, environment, health, behaviour, and mental state *(Table 1)* (Nicol *et al.,* 2020; Mellor and Beausoleil, 2015; Mellor and Reid, 1994). The first four categories are physical and functional domains that are measurable inputs from within and outside the body. These four domains can be accumulated into a fifth domain of mental state which depends on assessor knowledge and judgement of how species may respond to situations and to what extent they would be affected (Nicol *et al.,* 2020).

The Welfare Assessment Tool for Wild Cetaceans was developed by Nicol *et al*. (2020) to evaluate the welfare impacts of human activities on wild cetaceans *(Table 1)*. The application comes with a scenario and corresponding fact sheet that provides background on the species' biology, relevant threats, known impacts, and data gaps. Assessors complete a standardised score sheet where they rate the intensity of harm in each Domain from 1 – 4 *(Appendix Table 1)*. These scores are then used to determine the likely impact on the animal's mental state in Domain 5. Assessors also indicate how confident they are in their scores, estimate how long the harm might last, how often similar events are expected to occur, and how much of the animal's lifespan might be spent experiencing mild, moderate, or severe impact (Nicol *et al.,* 2020).

A flowchart outlining the proposed steps to advance this work is shown in *Figure 2* (Nicol *et al.,* 2020). However, it is important to note that this tool is a template that can be adapted for different cases and scenarios to improve its relevance and accuracy, and the assessment is ultimately based on the best available information and the assessors' judgement. To ensure that the assessment is robust and objective, comprehensive and species-specific information should be available, and assessors should have relevant expertise in animal welfare and/or cetacean research (Nicol *et al.,* 2020).

This framework has already proven successful in assessing the impacts of anthropogenic activities such as whale watching, vessel traffic, ship strike, entanglement, and marine contaminants on cetacean health and welfare (Rae *et al.,* 2023; Nicol *et al.,* 2020). Therefore, it has the potential to provide an assessment and serve as a valuable indicator of overall well-being of cetaceans in response to climate change. This in turn can help develop and support effective conservation measures.

Table 1: Cetacean Welfare Assessment Tool designed to guide the assessment of the harmful effects of human activities on the welfare of wild cetaceans. Domains 1 – 4 are physical and functional domains that are measurable inputs. Domain 5 takes aspects from domains 1 – 4 and infers the mental states based on assessor knowledge and judgement (Nicol et al., 2020).

<table>
<tr><th colspan="3">Survival-related factors (potentially observable)</th><th>Situation-related factors (potentially observable)</th></tr>
<tr>
<td>Domain 1.Nutrition
Consider potential impact of scenario on:
Foraging ability
Ability to ingest feed
Ability to digest feed
Prey availability, quality, variety
Energetic requirements</td>
<td>Domain 2.Environment
Consider potential impact of scenario on:
Presence of water-borne toxins, irritants
Aversive noise
Other disturbance preventing optimal habitat use
Constriction, confinement, trapping, entangling
Thermal
Unpredictable events
Increased predatory threat</td>
<td>Domain 3. Health
Consider potential impact of scenario on presence of:
Disease
Internal injury
External injury
Functional impairment (e.g. navigational)
Parasitism
Compromised respiration
Dehydration
Loss of body or muscle condition
Loss of sensory function</td>
<td>Domain 4: Behaviour
Consider potential impact of scenario on:
Impact of loss of key social partner/parent/calf
Separation from conspecifics
Limitations on communication or interaction with conspecifics
Compromised learning or cognition
Disturbed or inadequate sleep or rest
Aversive response to novel, unpredictable or threatening conditions
Altered time budgets (e.g. increased time spent on core activities such as feeding reducing time available for play, exploration, self-care, social relationships)</td>
</tr>
<tr><th colspan="2">Affective Experience (non-observable, inferred from domains 1 to 4)</th><th colspan="2"></th></tr>
<tr><th colspan="4">Domain 5. Your judgement about likelihood of animal experiencing a negative mental state associated with Domains 1-4 . Consider:</th></tr>
<tr>
<td colspan="2">Pain from internal or external cause
Hunger
Malaise
Anxiety, fear, panic
Discomfort
Fatigue, exhaustion, lethargy
Social loss, grief
Confusion</td>
<td colspan="2">Anger, rage, irritation
Nausea, sickness
Breathlessness, dizziness
Other cetacean-specific mental state (e.g. associated with compromised buoyancy)</td>
</tr>
</table>

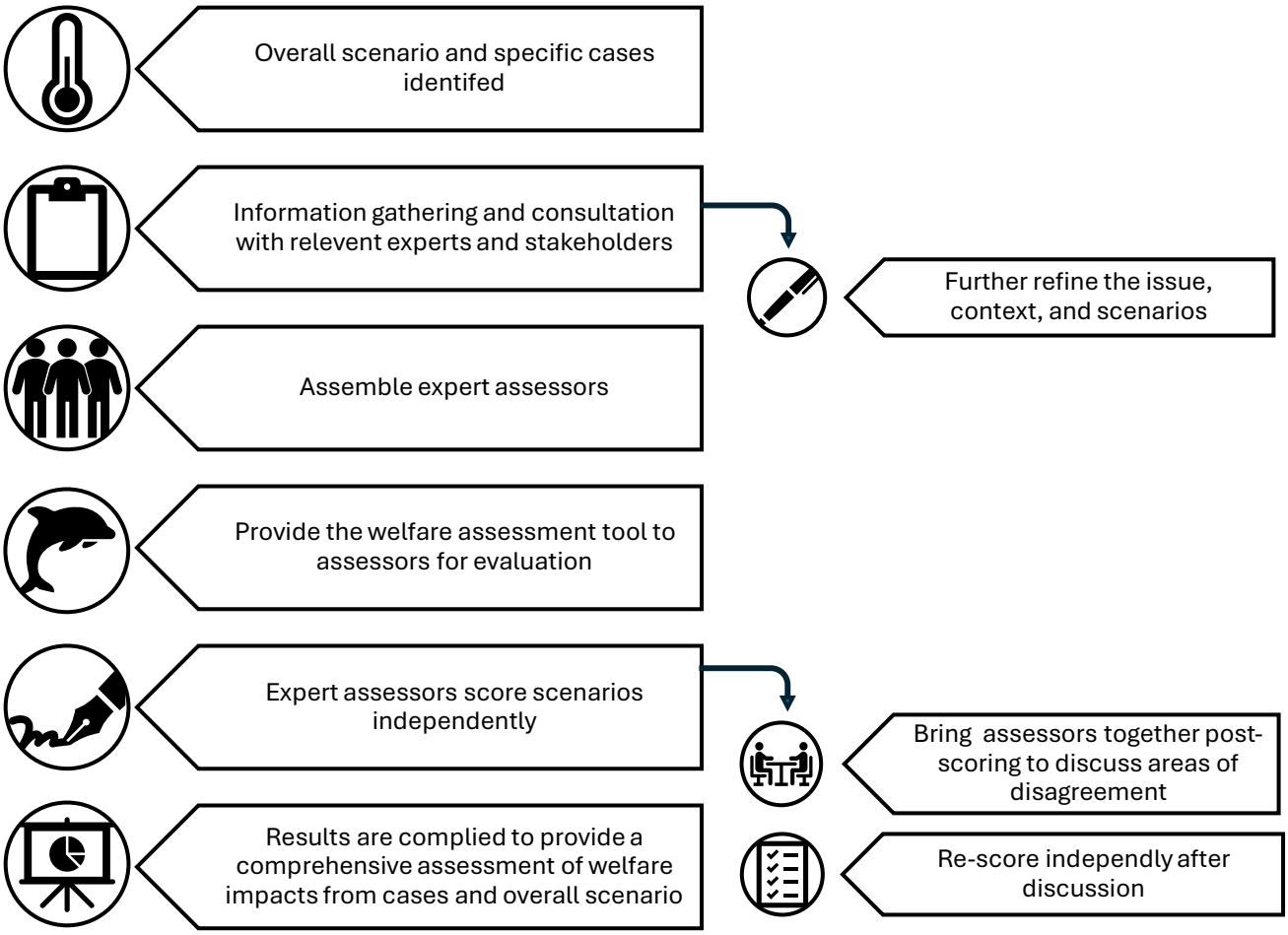

Figure 2: Process for conducting the Welfare Assessment Tool for Wild Cetaceans (adapted from Nicol et al., 2020)

1.4 Convention on Migratory Species (CMS)

Identifying and addressing the impacts of climate change on migratory species, including cetaceans, is a key focus of the Convention on Migratory species, as outlined in various CMS Resolutions and Decisions. For example, Resolution 14.1 (*Samarkand Strategic Plan for Migratory Species 2024–2032)* agreed at the 14th meeting of the Conference of the Parties to CMS (CMS COP14) includes Target 3.4:

> *"By 2032, the impact of climate change on migratory species and their habitats is reduced through mitigation and adaptation, including through nature-based solutions and/or ecosystem-based approaches and disaster risk reduction actions, while minimizing negative and fostering positive impacts on biodiversity."*

This is accompanied by the following explanation:

> *"Actions to eliminate or mitigate the negative impacts of climate change on migratory species are identified. This also includes the research and promotion of conservation and management tools applied to migratory species and the ecosystem services they provide, such as the enhancement of mitigation and adaptation against climate change*."

At the same meeting, Decision 14.72 (b) on Conservation Priorities for Cetaceans was adopted:

> *"The Scientific Council, subject to the availability of external resources and where applicable with support from the Aquatic Mammals Working Group, is requested to:*
>
> *b) in the context of threats from climate change, develop a report on the potential impacts that climate-induced migration will have on both the welfare and the conservation outcomes of affected cetacean species, and make recommendations to Parties;"*

An international Migratory Species and Climate Change Expert Workshop, held in Edinburgh in 2025, brought together experts to review the potential impacts of climate change on migratory species. The workshop report collated key findings on climate threats, vulnerable species, and adaptation and mitigation case studies, and explored how these findings align with international policy frameworks (Report of the Migratory Species and Climate Change Expert Workshop, 2025). However, it is anticipated that climate change will also exacerbate welfare concerns for cetaceans (Nicol *et al.,* 2020; Simmonds, 2017). As welfare is closely linked to survival and conservation outcomes, there has been growing interest in developing policies that not only support conservation strategies addressing ecological threats, but also explicitly address the welfare of cetaceans. This aligns directly with the aims of CMS to ensure the favourable conservation status of migratory species.

1.5 Aims and objectives

This report has been produced specifically in response to Decision 14.72(b). It aims to evaluate the impacts of climate change on cetacean species. The report is structured around four case study species representing the major ecological groupings of cetaceans: the Amazon river dolphin, common bottlenose dolphin, Cuvier's beaked whale and gray whale. These study species were chosen due to the availability of relevant literature on them, and their potential to represent trends across other similar, less well-studied species. The report uses both a review of relevant literature and interviews with species experts to provide an overview of the key impacts of climate change on cetacean ecology and welfare. The literature review was conducted to synthesise existing

knowledge on climate change impacts on cetaceans, and expert insights were gathered through informal conversations and their review of the case study drafts. The domains of the welfare assessment tool were applied to provide a guided interpretation of welfare impacts for each case study species rather than constituting a full formal welfare assessment.

The key findings of this report are then used to make recommendations to CMS Parties on ways to mitigate the impacts of climate change on both the welfare and conservation outcomes of cetacean species. This contributes towards addressing CMS Decision 14.72 (b) and advancing Target 3.4 of the Samarkand Strategic Plan, while also helping to advance the work of the Migratory Species and Climate Change Working Group.

2 Amazon River Dolphins

2.1 River dolphins

River dolphins reside exclusively in freshwater or brackish water (da Silva *et al.,* 2018). There are six species found within eight river basins across fourteen countries within South America and Asia *(Table 2 and Figure 3)*.

Table 2: All species of river dolphins, their resident river basins, and regions they reside in (River dolphins worldwide, n.d.).

Species	**Resident river basin**	**Region**
Amazon river dolphin (*Inia spp.*)	Amazon Orinoco Tocantins/Araguaia	South America
Tucuxi (*Sotalia fluviatilis*)	Amazon	South America
Indus river dolphin (*Platanista minor*)	Indus	Asia
Ganges river dolphin (*Platanista gangetica*)	Ganges-Brahmaputra-Meghna	Asia
Yangtze finless porpoise (*Neophocaena asiaeorientalis*)	Yangtze	Asia
Irrawaddy dolphin (*Orcaella brevirostris*) (3 subpopulations)	Mahakam Mekong Ayeyarwady	Asia

Figure 3: Global map showing the distribution of all species of river dolphin (River dolphins worldwide, n.d.).

2.2 Amazon river dolphins

2.2.1 Taxonomy and status

The taxonomy of Amazon river dolphins has proved controversial due to their widespread, complex, and fragmented distributions (da Silva *et al.,* 2018). There are currently four recognised species of Amazon river dolphin; the delphinid tucuxi *(Sotalia fluviatilis)*; the iniid Amazon or pink river dolphin *(Inia geoffrensis)*; the Bolivian boto *(Inia boliviensis)*; and the Araguaian boto *(Inia araguaiaensis)* (WWF, n.d.). The Amazon river dolphin is listed as *Endangered* on the IUCN Red List of Threatened Species, with an estimated population of > 10,000 individuals. However, evidence indicates ongoing population declines (WWF, 2023; da Silva *et al.,* 2018; Williams *et al.,* 2016).

2.2.2 Distribution

The Amazon river dolphin is a freshwater species native to South America, found in both the Amazon, Orinoco, and Tocantins/Araguaia River basins (da Silva *et al.,* 2018). Their range spans Brazil, Bolivia, Colombia, Ecuador, Peru, Guyana and Venezuela (da Silva *et al.,* 2018) *(Figure 4)*. Lower densities are observed in the Orinoco Basin (Venezuela and Colombia), and higher densities are found in the central Brazilian Amazon. This is believed to be linked to unique features, hydro-geomorphological characteristics, productivity, and level of human threats (Paschoalini *et al.,* 2021). River basins, channels,

confluences, tributaries, and lagoons are the main habitat types used by Amazon river dolphins and where hotspots in activity occur (Mosquera-Guerra *et al.,* 2021).

Figure 4: Map of South America showing the distribution of the Amazon river dolphin (orange lines) (da Silva et al., 2018).

2.2.3 Migration

The migration of the Amazon river dolphin is highly reliant on seasonal water level changes. There are four climatic seasons: low waters, rising waters, high waters, and falling waters. In the low-water season (July – December), freshwater is contained in the main river, confluences and channels in which dolphins occur. In the high-water season (January – June), water levels rise providing connection to floodplains and lagoons, in which dolphins can enter (da Silva *et al.,* 2018).

Sexual segregation occurs in response to these seasonal water level changes (Figure 5; Mosquera-Guerra *et al.,* 2023). During the high-water season females with dependent calves are more concentrated to floodplains and lagoons, which offer low currents, high productivity, and protection against predators (Mosquera-Guerra *et al.,* 2023). These environments are important for feeding and calving. In contrast, most adult males remain in the main river and channels during the high-water season, following fish that undertake upstream breeding migrations (Mosquera-Guerra *et al.,* 2023). During the low-water seasons, individuals converge to the main river, confluences, and channel habitats, which are used equally by both sexes (Mosquera-Guerra *et al.,* 2023). These environments are important for breeding and feeding (Mosquera-Guerra *et al.,* 2023).

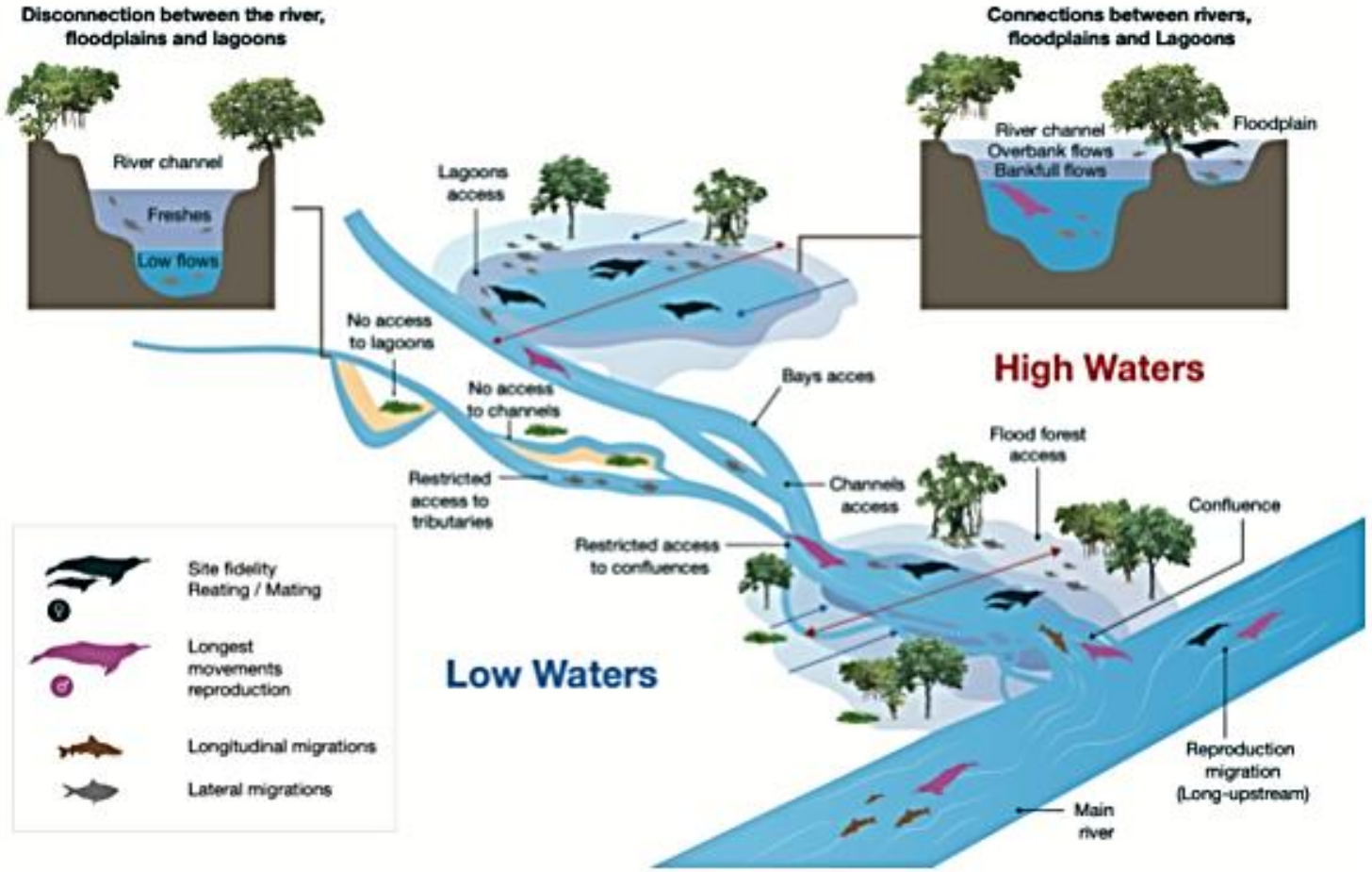

Figure 5: Impacts of water level changes on Amazon river dolphin ecology; during the high-water season, a rise in water levels connects the main river and floodplains which allows dolphins (especially females and calves) to enter these habitats; during the low-water season, a decrease in water levels disconnects floodplains from the main river causing dolphins to converge in confluences and channel habitats (Mosquera-Guerra et al., 2023).

2.2.4 Impacts of climate change

Climate change has been ranked as the highest threat to Amazon river dolphins (WWF, 2023), and exacerbates ongoing pressures such as overfishing of prey species, modified habitats from dams and deforestation, deliberate killing of dolphins for bait, and chemical pollution (Campbell et al., 2022; WWF, n.d.).

There is growing evidence that climate change impacts the Amazon river dolphin through higher water temperatures and changes in flood pulses (IWC, 2021). Due to their restricted distributions, high water temperatures directly impact dolphins through heat stress. Every year, at least four high temperature events occur, and in 2023 alone, a high temperature event occurred in Lake Tefé and Coari (Brazil) causing the death of approximately 330 dolphins (de Castro, 2024). Necropsies revealed evidence of obstructed blood flow, excess fluid in the lungs and heart, and internal haemorrhaging (*Report of the Migratory Species and Climate Change Expert Workshop*, 2025).

Due to the Amazon river dolphin's flood-pulse dependent migrations, changes to these pulses can cause individuals to become trapped in bodies of water that eventually dry up, causing thermal shock, burns, starvation and mortality (IWC, 2021). There has been an increase in the number of Amazon river dolphins becoming trapped in river segments over the last 10 years (IWC, 2021). In Orinoquia (Colombia), there have been at least 28 individuals, and in Rio Grande (Bolivia) there have been at least 58 individuals (IWC, 2021). As the spatial ecology of Amazon river dolphins is closely linked to their sex and maturity, females and calves are more susceptible to the impacts of changes in flood-pulses due to their reliance on floodplain and lagoon habitats. This differential exposure of sex-maturity-based spatial segregation can lead to disproportionate mortality among reproductive females and maturing calves.

In addition to direct impacts, increased water temperatures and changes in flood pulses can cause indirect impacts to Amazon river dolphins. For example, mass die-offs of fish species can lead to polluted conditions which impact Amazon river dolphins (IWC, 2012). Increased temperatures can also increase the transport of contaminants, leading to reduced reproductive success, weakened immune systems, and greater susceptibility to disease (*Report of the Migratory Species and Climate Change Expert Workshop*, 2025). Disruptions to the lateral and longitudinal migrations of fish have also reduced the survival of fish eggs and larvae, resulting in decreased prey availability (IWC, 2012). Additionally, changes to flood pulses promote the proliferation of cyanobacteria which can be toxic to Amazon river dolphins, and increasing wildfire prevalence in riparian forests pollutes air quality and decreases organic matter, an important food source for their prey species (IWC, 2012).

Overall, climate change poses a severe and multifaceted threat to Amazon river dolphins, intensifying existing pressures and directly endangering their survival

through rising temperatures, altered flood regimes, and disruptions to their habitat and prey.

2.2.5 Welfare and conservation outcomes

Building on the impacts outlined above, climate change presents not only an ecological challenge but also a significant welfare concern, with direct implications for the conservation of the species.

Drawing on observed impacts of climate change and guidance of the welfare assessment tool as a framework (Nicol *et al.,* 2020) *(Appendix Table 2),* the impact of climate change has been summarised in *Table 3*, including potential welfare implications, conservation implications and mitigation strategies. It is important to note that impacts to welfare are a guided interpretation and not a direct assessment.

Table 3: Impacts of climate change on Amazon river dolphin welfare and conservation, and potential mitigation strategies.

Impact of climate change	**Effect on Amazon river dolphin**	**Welfare implications**	**Conservation implication**	**Mitigation strategies**
Increase in water temperature	Physiological changes to dolphins	Thermal shock, internal injury, diseases, pain, discomfort, stress, increased energy expenditure, hunger	Increased mortality, reduced body condition, reduced reproductive rates	Early warning systems, translocation, use of climate models to forecast events to better prepare, fisheries-management, water management
	Migratory shifts/reduction in prey			
	Decreased water quality (pollution, contaminants, cyanobacteria)			
Changes in flood pulses	Isolation in shallow waters	Thermal shock, pain, burns, internal injury, stress, discomfort, dehydration, hunger	Increased mortality, increased vulnerability to predation and human activity	Translocation, identify and protect refuge areas, use of climate models to forecast events
	Habitat loss within floodplains and lagoons	Disruption to social activities (mating and calving)	Reduced reproductive rates, reduced	Protect, restore and/or develop critical freshwater

			calving success	habitats, regulate water management (dams)
	Habitat change with dam construction and deforestation	Disruption to social activities (mating, calving), migrations, and displacement	Reduced reproductive rates, reduced calving success, increased vulnerability to human activity, increased habitat fragmentation	Improve and regulate dam and deforestation planning

2.2.6 Current conservation

Amazon river dolphins benefit from a range of conservation efforts at national and international levels. These include:

- CMS (Appendix II)
- CITES (Appendix II)
- The South American River Dolphin Initiative (SARDI)
- National Action Plans
- The South American River Dolphin Conservation Management Plan (CMP) - International Whaling Commission
- Global Declaration for River Dolphins

SARDI was created in 2017 involving WWF participants in Faunagua (Bolivia); Fundación Omacha (Colombia); and Solinia (Peru); and Mamirauá Institute and Aqualie Institute (Brazil) (WFF, n.d.). SARDI aims to work collaboratively to mitigate the impact of threats to the Amazon river dolphin, and to preserve Amazon River habitats and ecosystem services for the benefit of both dolphins and people who depend on the river for resources (WWF, n.d.).

Specific to managing the threat of climate change SARDI have installed water monitoring stations to track temperature, water levels, and precipitation in which real-time alerts are sent to SARDI members' phones when a threshold that relates to a potentially catastrophic climatic event for Amazon river dolphins is met. Additionally, protocols have been developed for the management and mitigation of dolphin entrapments (IWC, 2021;

SARDI, n.d.; WWF, n.d.) with researchers, locals, and fishermen have been trained to rescue and relocate individuals to areas where their survival is more likely (IWC, 2021).

These initiatives have contributed a substantial amount of knowledge and information on Amazon river dolphins and ways to support their adaptation to climate change. However, several critical data and management gaps remain:

- **Declining population trends**: Although limited, the available range-wide estimates of densities and abundance suggest that the population is declining. This makes it both challenging and urgent to quantify and manage the impacts of climate change.
- **Limited capacity for management:** Even though there are management responses to increased temperatures in place, such as daily patrols, animal counts and documentation of behaviours, there is extremely limited information on how Amazon river dolphins react to heat stress, with no procedures established on how to treat or mitigate the effects of high temperatures, and limited information on individual tolerances to temperature change within the environment (*Report of the Migratory Species and Climate Change Expert Workshop*, 2025).
- **Limited capacity for translocation**: While a translocation protocol has been developed and efforts during catastrophic events have had some success, they are often logistically and economically unfeasible, exceeding current response capabilities.
- **Limited capacity for refuge areas**: The Amazon River lacks infrastructure for controlled environments that can be refuge areas. Therefore, developing a comprehensive rehabilitation plan for the Amazon river dolphin is challenging *(Report of the Migratory Species and Climate Change Expert Workshop,* 2025).
- **Protected area effectiveness**: Although 88 areas in South America are designated as protected or conserved, most river dolphins are believed to live outside these areas and are not prioritised for targeted conservation.
- **Absence of welfare considerations**: Welfare considerations are largely missing from existing conservation plans, representing a significant gap in addressing the broader challenges the species faces regarding their survival and reproduction.

Overall, despite existing conservation measures, current efforts remain insufficient in the face of the intensifying pressure of climate change. With the impacts of climate change expected to increase, more comprehensive and coordinated conservation strategies will be required to ensure the long-term survival of the species.

2.2.7 Potential actions

Below are possible actions that may support Amazon river dolphin conservation in regard to climate change:

1. **Population and Threat Monitoring**
   - Continue and expand range-wide efforts to assess the distribution, abundance, and trends of Amazon river dolphin populations to quantify the impacts of climate change.
   - Continue and expand real-time hydrological monitoring to inform early warning systems and translocation protocols, by sharing successful methodologies between countries where river dolphin populations overlap.
   - Use hydrological and climate models to predict potential catastrophic events and make plans to be better prepared for their impacts.
   - Continue and support translocation of stranded individuals by incorporating pre-, during-, and post-release monitoring, following IUCN best practice guidelines (IUCN/SSC, 2013) and including considerations of welfare in response to monitoring results.
   - Develop and implement a welfare assessment tool to evaluate the range of impacts of climate change on dolphin health and wellbeing.
   - Management of indirect pressures (bycatch, overfishing of prey species, pollution etc.) to reduce cumulative impacts on river dolphins (Trujillo *et al.,* 2021).

2. **Habitat Management**
   - Identify and protect critical habitats in the main river, confluences, tributaries, and lagoons that are essential for feeding, calving, and reproduction.
   - Establish and protect migration corridors to maintain habitat connectivity.
   - Consider adaptive management to maintain natural flow regimes (e.g. dam management, deforestation management, lagoon/channel construction).
   - Consider establishing refugee areas that provide stable environments during periods of stressful environmental conditions.

3. **Coordination and Capacity Building**
   - The distribution of the Amazon river dolphin is restricted to just seven countries. Of these, four - Brazil, Bolivia, Ecuador, and Peru - are Parties to the CMS. Strengthened transboundary cooperation among all Range States is critical to effectively mitigate climate change impacts on Amazon river dolphin populations and ensure coordinated conservation efforts across their full geographic range.
   - Create more comprehensive and harmonised approaches across multilateral environmental agreements (MEAs) to mitigate the effects of climate change on the Amazon river dolphin by supporting collaborative efforts between

organisations, researchers, and policymakers *(Report of the Migratory Species and Climate Change Expert Workshop,* 2025).

- The IWC Conservation Management Plan provides a scientific and management framework that contracting governments have committed to. While the plan does not explicitly address climate change, some threats and objectives may indirectly relate to it. Therefore, direct integration of climate change impacts on the Amazon river dolphin could strengthen the plan (*Report of the Migratory Species and Climate Change Expert Workshop,* 2025; Trujillo *et al.,* 2021).

3 Common Bottlenose Dolphins

3.1 Taxonomy and status

Common bottlenose dolphins used to be considered as two species: the Common bottlenose dolphin *(Tursiops truncatus)* and the Indo-Pacific bottlenose dolphin *(Tursiops aduncus)* (Wells *et al.,* 2019). However, now four subspecies are currently recognised; the nominotypical subspecies *(T. t. truncatus)*, the Black Sea bottlenose dolphin *(T. t. ponticus),* the Lahille's bottlenose dolphin *(T. t. gephyreus),* and the Eastern Tropical Pacific bottlenose dolphin *(T. t. nuuanu)* (Wells *et al.,* 2019).

The overall conservation status of common bottlenose dolphins is classified as *Least Concern* (Wells *et al.,* 2019). However, several populations are of conservation concern, such as the Fiordland subpopulation in New Zealand *(Critically Endangered),* the Mediterranean subpopulation *(Vulnerable)* and the Black Sea subspecies *(Endangered)* (Wells *et al.,* 2019). Global abundance estimates suggest a population of around 750,000 individuals, with population trend as unknown. Much of the species' offshore population abundance remains largely unknown, and thus abundance is thought to be considerably higher (Wells *et al.,* 2019).

3.2 Distribution and migration

Common bottlenose dolphins have worldwide distributions in all three major ocean basins and the Mediterranean Sea *(Figure 6)* (Wells *et al.,* 2019). They occur at tropical and temperate latitudes, and within inshore, coastal, shelf, and oceanic waters (Wells *et al.,* 2019).

Distinct ecotypes exist within inshore and offshore areas (Wells *et al.,* 2019). Inshore habitats include rivers, estuaries, bays, lagoons and shallow coastal regions, and offshore habitats include oceanic islands, deep waters off the continental shelf, and the open ocean (Wells *et al.,* 2019).

Inshore populations are typically residential, with defined long-term home ranges. Inshore populations also exhibit seasonal migrations, and occasional long-range movements (Wells *et al.,* 2019). Generally, common bottlenose dolphins tend to move northward in spring and summer, and southward during autumn and winter as the species tracks warmer water temperatures, prey availability and low salinity (Wilson *et al.,* 1997; Taylor *et al.,* 2016). Offshore populations are thought to have broader ranges and are more migratory, but their migration patterns are less well understood (Wells *et al.,* 2019).

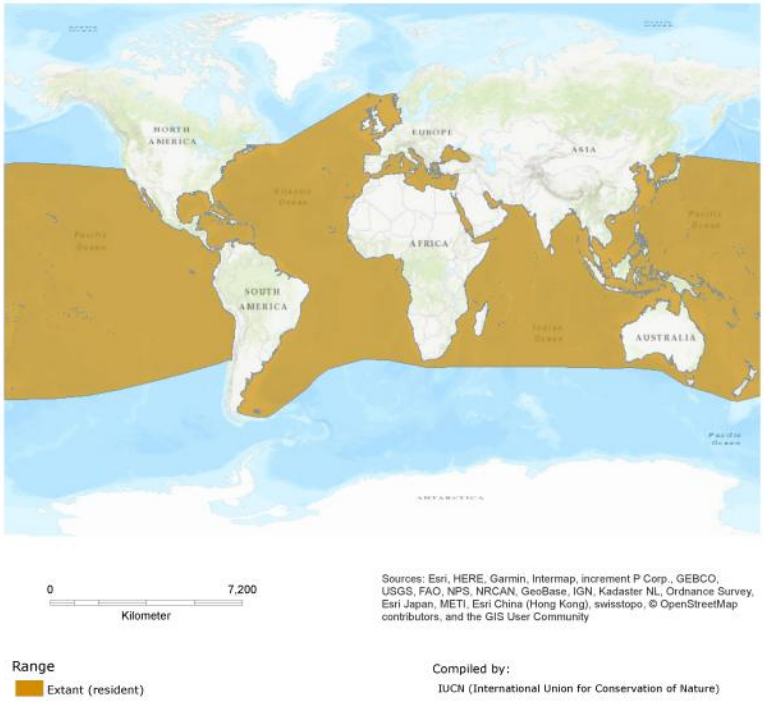

Figure 6: Global distribution of common bottlenose dolphin (Wells et al., 2019).

3.3 Impacts of climate change

It is predicted that range shifts will occur in response to climate change as common bottlenose dolphins follow changes in their prey distributions or adjust their range to remain within their thermal preferences (Martin *et al.,* 2023). This has already been observed around the UK, where individuals from the Moray Firth are now frequently seen further south, near St Andrews Bay and the Tay Estuary in eastern Scotland, suggesting either a shift or a southward expansion (Cheney *et al.,* 2013; Cheney *et al.,* 2014; Evans & Waggitt, 2020; Martin *et al.,* 2023). In south-west England, particularly around Devon and Cornwall, common bottlenose dolphins appear to be extending their range along the English Channel, with sightings reported as far east as Sussex (Corr, 2024; Martin *et al.,*

2023). On the west coast of Ireland, common bottlenose dolphins in the Shannon Estuary seem to be expanding into Brandon Bay (Charish *et al.,* 2021; Martin *et al.,* 2023).

There are similar findings in the Mediterranean Sea, where increased sea surface temperatures have negatively influenced both the occurrence and group size of common bottlenose dolphins, and their home ranges have increased threefold (La Manna *et al.,* 2023). The CMS Migratory Species and Climate Change Expert Workshop also highlighted that the Mediterranean Sea population is expected to be impacted by climate change in several ways, such as changes in prey availability and abundance, increased intraspecies competition, introduction of novel pathogens, potential thermal stress, and enhanced cumulative impacts (Report of the Migratory Species and Climate Change Expert Workshop, 2025). In Australia, increased temperatures have led to significant marine heatwaves in the Shark Bay World Heritage Area (Western Australia), causing female reproductive rates to drop significantly and impact survival rates (Wild *et al.,* 2019). These findings suggest that the impacts of climate change are reducing reproductive output and survival, which reduces the population's viability (Wild *et al.,* 2019).

Increased rainfall and freshwater runoff in coastal areas is causing nutrient enrichment, resulting in toxic algal blooms in coastal areas (Evans & Waggitt, 2020). These algal blooms can cause mass mortalities of common bottlenose dolphins (Evans & Waggitt, 2020). Additionally, in Australia, increased rainfall followed by periods of drought can expose common bottlenose dolphins to Freshwater Skin Disease (FWSD) (Duignan *et al.,* 2020). FWSD causes the dolphin's skin to become infected by fungal, bacterial and algal species, and the outer layer of the skin becomes swollen and blistered leading to open lesions (Duignan *et al.,* 2020). FWSD has led to significant mortality events in Victoria's Gippsland Lakes in 2007 and Swan-Canning Riverpark (Western Australia) in 2009 (Duignan *et al.,* 2020). There is also a concern that climate change has the potential to increase pathogen development and impact survival rates, disease transmission, and host susceptibility, increasing the common bottlenose dolphin's vulnerability to diseases even further (Evans & Waggitt, 2020; Martin et al., 2023).

In Western Australia, climate change related impacts on the frequency of extreme El Niño–Southern Oscillation (ENSO) events have been linked to increased vulnerability of coastal common bottlenose dolphin populations. The ENSO is a naturally occurring climate phenomenon compromised of two phases: El Niño and La Niña. El Niño is characterised by warmer global temperatures, while La Niña years are typically cooler (Salvadeo *et al.,* 2015). Studies suggest that climate change may be leading to more frequent and intense El Niño and La Niña events (Calvin *et al.,* 2023). In Western Australia, the ENSO affects the strength of the Leeuwin Current, and in turn marine ecosystems. During La Niña events, the current is stronger and has previously had positive impacts on marine ecosystems, with dolphin abundance remaining stable throughout (Sprogis *et al*., 2018). During El Niño events the current is weaker with cooler

sea surface temperatures and increased rainfall. This has resulted in temporary declines in abundance and changes in movement patterns of common bottlenose dolphin, likely associated with changes in dolphin prey availability and/or unfavourable water quality conditions. However, increased frequency of El Niño events, as predicted by climate modelling, may result in long-term impacts to common bottlenose dolphin abundance and distribution (Sprogis *et al.,* 2018).

Overall, climate change is having widespread and varied effects on common bottlenose dolphin populations around the world. Inshore populations also experience cumulative effects from climate change, due to existing pressures from bycatch, shipping, disease, biotoxins, chemical pollution, and noise pollution (Wells *et al.,* 2019). The full extent of climate-related impacts on offshore populations remains largely unknown (Wells *et al.,* 2019). Though it is evident that common bottlenose dolphins exhibit a strong ability to adapt to changing conditions, the ecological consequences of climate change may be too sudden or disruptive for successful adaptation, leading to negative impacts on population viability.

3.4 Welfare and conservation outcomes

Building on the impacts outlined above, climate change presents not only an ecological challenge but also a significant welfare concern for common bottlenose dolphins, with direct implications for the conservation of the species.

Drawing on observed impacts of climate change and the welfare assessment tool as a framework (Nicol *et al.,* 2020) *(Appendix Table 3),* the impact of climate change on the common bottlenose dolphin has been summarised in *Table 4*, including potential welfare and conservation implications, and mitigation strategies. It is important to note that impacts to welfare are a guided interpretation and not a direct assessment.

Table 4: Impacts of climate change on common bottlenose dolphin welfare and conservation, and potential mitigation strategies

Impacts of climate change	Effect on common	Welfare implications	Conservation implications	Mitigation strategies

	bottlenose dolphin			
Increased temperatures	Distribution shifts Prey availability/shifts Decreased abundance	Thermal stress, stress, increased energy expenditure, hunger, disruption to social behaviour	Increased mortality, reduced body condition, reduced reproductive rates	New or updated protected areas and management plans that encompass the shift of critical areas, management of anthropogenic activity (e.g. fisheries, vessels), use of climate models to forecast events to better support range shifts
Increased frequency in El Niño and La Niña events				
Extreme weather events (drought and rainfall)	Freshwater skin disease	Increase in disease and injuries, pain, discomfort, stress, mass mortalities	Reduced health, increased mortality	Use of climate models to forecast events to better support range shifts, improve water quality
	Toxic algal blooms			

3.5 Current conservation

Common bottlenose dolphins benefit from a range of conservation efforts at national and international levels. These include:

- CMS (Appendix II)
- CITES (Appendix II)
- Agreement on Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)
- Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS)
- Annex II and IV of The European Union's Habitats Directive; Designated Special Areas of Conservation (SACs)

- Annex II on The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention); Designated Areas of Special Conservation Interest (ASCIs)
- Regional marine conventions, including the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), the Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention), the Baltic Marine Environment Protection Commission (HELCOM) and the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (the Cartagena Convention)
- Memorandum of Understanding for the Conservation of Cetaceans and Their Habitats in the Pacific Islands Region
- Memorandum of Understanding Concerning the Conservation of the Manatee and Small Cetaceans of Western Africa and Macaronesia
- National legislation, such as the Marine Mammal Protection Act of 1972 (United States) and the Environment Protection and Biodiversity Conservation Act (Australia)

Although these frameworks provide some protection, the majority were not originally designed to address the emerging and complex threats posed by climate change. Therefore, several critical data and management gaps remain in regard to climate change:

- **Lack of overall population data**: In many regions (especially oceanic or less-studied coastal areas), long-term monitoring is sparse and accurate population estimates are lacking or have not been repeated recently, limiting the ability to quantify climate-related threats and develop targeted conservation responses to specific populations.
- **Adaptation potential:** Common bottlenose dolphins have exhibited the ability to adapt to changing conditions, however, it is uncertain if they can continue to adapt at a quick rate.
- **Population specific vulnerabilities:** There is clear variability in vulnerability to climate change among different populations of common bottlenose dolphins. For example, small, geographically isolated populations, such as the Mediterranean subpopulation, may face greater risks due to limited habitat range, reduced genetic diversity, and heightened exposure to local stressors.
- **Cumulative effects:** The interactions between climate change and other stressors to common bottlenose dolphins are poorly understood, making it difficult to assess the severity of impacts.
- **Protected area effectiveness**: Common bottlenose dolphins potentially benefit from several national and international conservation instruments and are protected through Marine Protected Areas (MPAs). However, these frameworks may not explicitly address the impacts of climate change. Additionally, these

areas are static which can be a concern when species distributions and migrations shift resulting in MPAs not being effective.

- **Absence of welfare consideration**: Welfare considerations are largely missing from existing conservation plans, representing a significant gap in addressing the broader challenges facing the species' reproduction, health, and survival.

Overall, despite existing conservation measures, current efforts remain insufficient in the face of the intensifying pressure from climate change. With the impacts of climate change expected to increase, more comprehensive and coordinated conservation actions will be required to ensure the long-term survival of the species.

3.6 Potential actions

Below are possible actions to support common bottlenose dolphin conservation in regard to climate change:

1. **Population and Threat Monitoring**
   - Improve range-wide efforts to assess the distribution, abundance, and trends of common bottlenose dolphin inshore and offshore populations to quantify the impacts of climate change to different ecotypes and populations.
   - Use climate models to predict significant climatic events and use the model results to be better prepared for such events and their impacts.
   - Develop and implement a welfare assessment tool to evaluate the range of impacts of climate change on common bottlenose dolphin health and wellbeing.
   - Manage indirect pressures (fisheries, water quality, chemical pollution, noise pollution, etc.) to mitigate synergistic effects of climate change.
2. **Habitat Management**
   - Identify and protect critical habitats, both inshore and offshore, to accommodate common bottlenose dolphins' shifting distributions across their range.
   - Identify and protect critical sections of common bottlenose dolphin migration routes (e.g. areas of fidelity, home ranges).
   - Reassess designated protected areas (e.g. MPAs) to ensure they encompass key locations and habitats used by the species in the light of anticipated climate change impacts.
3. **Coordination and Capacity Building**
   - Out of the 133 CMS Parties listed, approximately 100 – 105 have coastlines or marine access where common bottlenose dolphins are known to occur. Therefore, enhanced transboundary collaboration, including sharing data,

monitoring techniques, and management outcomes, will help to improve understanding of the different populations, their migratory movements, and the threats they face from climate change.

- Strengthen existing networks and/or create an international network of experts and stakeholders (scientists, communities, authorities) to further support conservation actions in response to climate change.

4 Cuvier's Beaked Whales

4.1 Taxonomy and status

Cuvier's beaked whale *(Ziphius cavirostris)* is recognised as a single species throughout its range (Baird *et al.,* 2020). Currently, it is listed as *Least Concern*, with a global population of at least 100,000 individuals, though population trends are unknown (Baird *et al.,* 2020). There is also evidence of a genetically isolated subpopulation within the Mediterranean which is listed as *Vulnerable*. This subpopulation has fewer than 10,000 mature individuals, and is experiencing population declines (Cañadas & Notarbartolo di Sciara, 2018).

4.2 Distribution and migration

Cuvier's beaked whales are widely distributed in offshore waters from the tropics to cold-temperate regions but are not known to occur in high latitude polar waters *(Figure 7)* (Baird *et al.,* 2020). They tend to occur in deep waters associated with steep continental slopes, oceanic islands, submarine canyons and seamounts (Allen *et al.,* 2012; Shearer *et al.,* 2019; Baird *et al.,* 2020). They can be found in semi-enclosed seas, such as the Mediterranean Sea, Gulf of California, Gulf of Mexico, Caribbean Sea, the Sea of Japan (East Sea), and Sea of Okhotsk (Baird *et al.,* 2020). They are also found around islands, including the Hawaiian Islands, the Bahamas, San Clemente Island (California), and the Canary Islands (Spain) (Allen *et al.,* 2012). However, little is known about their offshore distributions.

Cuvier's beaked whales display vertical migrations in the water column as part of their normal behaviour, exhibiting long and deep dives with little surface duration (Shearer *et al.,* 2019). They perform at least three types of dives: short and shallow dives during surfacing series (function primarily for gas exchange); intermediate dives (to reduce predator detection); and long and deep foraging dives (echolocation clicks are only produced below 200 m) (Baird, 2019). The deep dives dominate their activity patterns, and are nearly continuous, occurring both day and night (Shearer *et al.,* 2019). Some of these deeper dives reach depths of 2,992m and durations of 137.5 minutes (Schorr *et al.,*

2014). Deep dives are thought to follow the movements of their prey species, such as cephalopods, small fish, and crustaceans (West *et al.,* 2017; Baird, 2019).

Figure 7: The global distribution of the Cuvier's Beaked Whale (Baird et al., 2020).

Cuvier's beaked whales demonstrate a high degree of site fidelity in their home range movements, with little displacement from their core regions (Foley et al., 2021). However, long range movements involving offshore crossing of international boundaries have been recorded in the Mediterranean subpopulation (CMS, 2014).

4.3 Impacts of climate change

Cuvier's beaked whales around Hawai'i have been affected by climate variability, particularly through the ENSO. El Niño events bring drier winters, warmer ocean temperatures, and increased hurricane risk to the region, while La Niña events are associated with wetter winters, cooler temperatures, fewer hurricanes, and higher sea levels (Barrios *et al.,* 2024).

Variability in the frequency and intensity of El Niño and La Niña events are correlated with changes in Cuvier's beaked whales' movements and distribution, with a significantly higher presence of the species recorded at several sites in the Pacific Ocean during El Niño events compared to La Niña periods (Barrios *et al.,* 2024; Schoenbeck *et al.,* 2024). During El Niño events, Cuvier's beaked whales showed a marked preference for nearshore waters along the west coast of Hawai'i with sighting rates almost double those seen during La Niña events (Barrios *et al.,* 2024). Similar patterns were observed in the

Southern California Bight, where acoustic monitoring detected an increase in Cuvier's beaked whale presence during El Niño events (Schoenbeck *et al.,* 2024).

It has been hypothesised that the increase in Cuvier's beaked whales in relation to El Niño events is due to a shift in prey availability (Barrios *et al.,* 2024; Schoenbeck *et al.,* 2024) or predation avoidance (Barrios *et al.,* 2024). Several squid and fish species that are prey of Cuvier's beaked whales shift their distribution or increase recruitment during periods of El Niño (Jun Chen *et al.,* 2007, Keyl *et al.,* 2008; Koslow *et al.,* 2014). Additionally, killer whales were not sighted during the El Niño periods but were sighted after El Niño winters (Barrios *et al.,* 2024), which may influence Cuvier's beaked whales' patterns of occurrence as they can present a predation threat.

Furthermore, predictive studies suggest that beaked whales are likely to experience continued range shifts towards higher latitudes due to altered prey resources and rising ocean temperatures, resulting in reduced availability of suitable habitats (Feyrer *et al.,* 2024). These changes in movement patterns driven by climate change could increase exposure to other stressors faced by Cuvier's beaked whales, especially the main threat of human-induced underwater noise (Feyrer *et al.,* 2024; Baird, 2020). Studies have shown that Cuvier's beaked whales that are exposed to increased anthropogenic sounds increase dive durations, alter foraging behaviours, avoid sound sources, and are linked to mass stranding events (Curtis *et al.,* 2020; Hooker *et al.,* 2019; Falcone *et al.,* 2017; Schorr *et al.,* 2014). These changes have also been linked to reduced reproductive success and population declines (Moore & Barlow, 2013; New *et al.,* 2013), as well as pathologies such as vascular congestion and haemorrhages, gas bubble-associated lesions, and fat emboli within vital organs (D'Amico *et al.,* 2009; Fernández et al. 2005; Jepson *et al.,* 2003).

Overall, the impacts of climate change on beaked whales are difficult to observe and predict, as these species are already poorly understood. While effects are likely occurring, they remain largely unknown.

4.4 Welfare and conservation outcomes

Building on the impacts outlined above, climate change presents not only an ecological challenge but also a significant welfare concern to Cuvier's beaked whales, with direct implications for the conservation of the species.

Drawing on observed impacts of climate change and guidance of the welfare assessment tool as a framework (Nicol *et al.,* 2020) *(Appendix Table 4),* the impact of climate change has been summarised in *Table 5,* including potential welfare implications, conservation outcomes and mitigation strategies. It is important to note that impacts to welfare are a guided assumption and not a direct assessment.

Table 5: Impacts of climate change on Cuvier's beaked whale welfare and conservation, and potential mitigation strategies.

Impact of climate change	Effect on Cuvier's beaked whale	Welfare implications	Conservation implications	Mitigation strategies
Increased temperature	Distribution shifts (higher latitudes) Distribution shifts in prey	Reduced habitat, disruption to natural diving patterns, hunger, malnutrition, stress, increased energy expenditure, increased predator interaction, increased injuries (internal), increased conflict with humans	Increased mortality, reduced reproduction	New or updated protected areas and management plans that encompass the shift of critical areas and depths, anthropogenic activity management (e.g. fisheries, navy)
Increased frequency in El Niño and La Niña events	Distribution shifts (nearshore)			
	Distribution shifts (vertical)			

4.5 Current conservation

Cuvier's beaked whales benefit from a range of conservation efforts at national and international levels. These include:

- CMS (Appendix I)
- CITES (Appendix II) (CITES)
- Specially Protected Areas and Wildlife (SPAW) protocol
- Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)
- Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS)
- Memorandum of Understanding concerning the Conservation of the Manatee and Small Cetaceans of Western Africa and Macaronesia

- Memorandum of Understanding for the Conservation of Cetaceans and Their Habitats in the Pacific Islands Region
- Annex IV of EU Habitats Directive
- Annex II on the Bern Convention
- National legislation, such as the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) in the United States of America

Although these frameworks provide some protection, the majority were not originally designed to address the emerging and complex threats posed by climate change. Therefore, several critical data and management gaps remain in relation to climate change:

- **Lack of overall population data**: Due to their deep-water, offshore distribution and limited time spent at the surface, the species remains significantly data deficient. Thus, quantifying the pressure of climate change is challenging.
- **Lack of effective monitoring**: Within the research that has been conducted, the sample sizes are typically small and as such conclusions are often associated with substantial uncertainty.
- **Effectiveness of protection:** No direct management or conservation measures have yet been taken for this species with regards to climate change.
- **Absence of welfare considerations**: Welfare considerations are largely missing from existing conservation plans, representing a significant gap in addressing the broader challenges facing the species survival.

4.6 Potential actions

Below are possible actions that may support Cuvier's beaked whale conservation in relation to climate change:

1. **Population and Threat Monitoring**
    - Improve range-wide efforts to assess the distribution, migration, abundance, and trends of Cuvier's beaked whale populations to quantify the impacts of climate change.
    - Use climate models to predict significant El Niño and La Niña events and how to be better prepared for them and their impacts.
    - Develop and implement a welfare assessment tool to evaluate the range of impacts of climate change on Cuvier's beaked whales' health and wellbeing.
    - Management of indirect pressures (fisheries, naval sonar, noise pollution etc.) to mitigate synergistic effects of climate change.
2. **Habitat Management**

- Identify and protect critical habitats both inshore and offshore to encompass Cuvier's beaked whale distributions across their range.
- Establish and protect critical sections of Cuvier's beaked whale migration routes (e.g. areas of fidelity, home ranges), and vertical migration corridors to maintain access to deep-water foraging habitats and minimise disruptions from anthropogenic noise throughout the water column.

3. **Coordination and Capacity Building**
   - Out of the 133 CMS Parties, more than 50 are known or highly likely to have Cuvier's beaked whales present in their waters. Therefore, to ensure protection across their whole distribution and migratory routes, enhanced transboundary collaboration among research groups and promoting sharing of data, monitoring methods, and management outcomes will help to improve understanding of the population and threats from climate change.
   - Strengthen existing networks and/or create an international network of experts and stakeholders (scientists, communities, authorities) to further support conservation actions in relation to climate change.

5 Gray Whales

5.1 Taxonomy and status

Gray whales *(Eschrichtius robustus)* can be grouped into two populations: the Eastern North Pacific (ENP) population and the Western North Pacific (WNP) population (Cooke, 2018; Cooke *et al.,* 2018). The ENP has a prominent subgroup known as the Pacific Coast Feeding Group (PCFG). Currently, the ENP population is listed as *Least Concern*, with a stable population of around 25,000 – 30,000 individuals, although population estimates from 2024/25 are roughly half this following a substantial decline in reproductive rates (Cooke, 2018; Eguchi et al., 2023; 2025; Lang et al., 2025). The PCFG subpopulation is estimated to make up 250 individuals (Cooke, 2018). The WNP population is listed as *Critically Endangered*, with an increasing population trend, but abundance is estimated to be less than 250 individuals (Cooke *et al.,* 2018).

5.2 Distribution and migration

General distribution

Gray whales are distributed in the North Pacific Ocean and are typically found in shallow coastal waters (Perrin *et al.,* 2009) *(Figure 8)*.

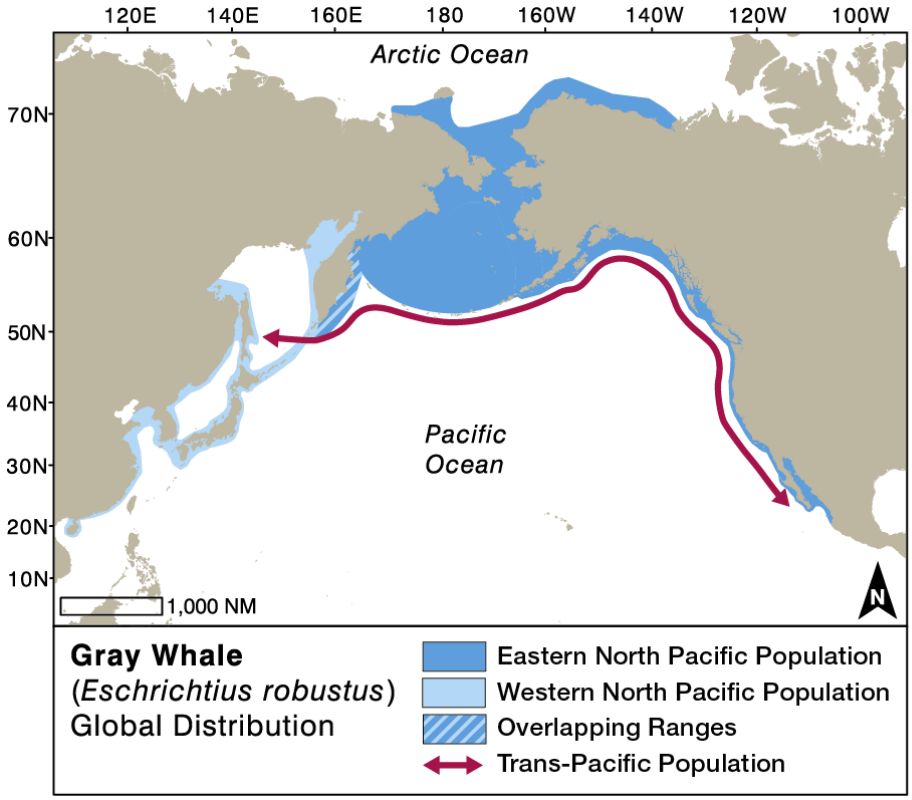

Figure 8: The distribution of gray whale populations (dark blue = ENP, light blue = WNP) (Perrin et al., 2009).

Autumn southward migration (breeding grounds)

In the autumn, both populations of gray whales travel south from their feeding grounds to their breeding grounds and gather along the west coast of Mexico (mainland, Baja California, Gulf of California) (Cooke, 2018; Cooke *et al.,* 2018). These areas are favoured due to shallow depths, warm waters, high salt content, and protection from predators (Mike, 2023). On average, the southward migration from the Arctic starts in October, passing California's coast in December to January. Whales begin to arrive at their breeding grounds in December and reach maximum abundance in February (Swartz, 1986).

Spring northward migration (feeding grounds)

In the spring, gray whales travel north and migrate to their feeding grounds. The ENP migrate to northwestern Bering Sea and the southern Chukchi and Beaufort seas (Arctic) (Cooke, 2018), the PCFG migrate along northern California to British Columbia, and occasionally into southeastern Alaska, and the WNP migrate to Okhotsk, Kamchatka and Sakhalin (Russia) (Cooke *et al.,* 2018). The departure of gray whales from the breeding grounds is segregated by age, sex and reproductive condition (Swartz, 1986). Newly pregnant females are the first northward migrants, departing in mid-February (Swartz,

1986). This is then followed around two weeks later by adult males, anoestrous females and immatures of both sexes (Swartz, 1986). The departure of females with calves occurs last, meaning that by late March, the breeding ground is only occupied by female-calf pairs, with some staying until late-April and early-May (Swartz, 1986).

5.3 Impacts of climate change

Historically, human persecution was believed to be the cause of low numbers in the ENP population and extinction of the WNP breeding population (Cooke, 2018). The ENP population has now recovered to near carrying capacity, but the WNP population has not fully recovered (Cooke, 2018). Both populations are subject to anthropogenic threats such as entanglements in fishing gear and ship strikes, and climate change is expected to exacerbate these existing threats while also introducing new challenges (Cooke, 2018).

Feeding grounds

ENP gray whales are threatened by climate change due to their strong dependence on sea ice, which supports their feeding ecology in the Arctic region. Seasonal sea ice retreat and advance influences the productivity and availability of benthic prey, such as amphipods, which rely on Particulate Organic Carbon (POC) that sinks from under-ice algal blooms (Stewart *et al*., 2023). However, sea ice is melting earlier in spring and forming later in autumn, meaning the open-water period is lengthened and less POC sinks to the sea floor (Stewart *et al.,* 2023). Additionally, decreased sea ice cover has allowed stronger currents to flow over the shallow basins, reducing the availability of important sediments required for amphipod habitats (Stewart *et al.,* 2023). As gray whales primarily feed on amphipods, the ongoing decline in sea ice and shifting melt patterns are disrupting the Arctic food web, leading to reduced prey abundance and quality in key feeding areas (Stewart et al., 2023).

Initially, melting sea ice provided greater access to feeding areas, supporting an increase in gray whale abundance (Salvadeo *et al.,* 2015). However, the long-term impacts of this do not seem to be favourable (Stewart *et al.,* 2023; Pirotta *et al.,* 2024) and large-scale ecosystem change in ENP gray whale feeding grounds due to climate change is thought to be the most likely cause of the substantial decline in this population from 2015/16 to 2024/25 (Perryman et al., 2022). When low prey biomass coincides with high ice cover, gray whales can experience major mortality events (1978, 1999 and 2019), resulting in population declines of 15 to 20 percent for each event (Stewart *et al.,* 2023). These mortalities have been linked to an increase in natural mortality, poorer body condition, and in particular, lower birth rates (Stewart *et al.,* 2023). This suggests that major mortality events are linked to environmental changes (Stewart *et al.,* 2023).

Gray whales may possess some capacity to adapt to changing environmental conditions. Since 2000, significant declines in body length (especially in females and calves) have been documented (Pirotta *et al.,* 2024). The decline in length has been correlated with the trends in two climatic indices, suggesting a plastic response to changing environmental conditions (Pirotta *et al.,* 2024). However, this response may be unsustainable over the long-term, as smaller sizes limit the amount of reserves an individual can carry, impacting their ability to survive, reproduce, and cope with other pressures (Pirotta *et al.,* 2024).

Additionally, poleward shifts in gray whale feeding locations have been documented, as well as rare reports of individuals outside their natural habitats, such as the Mediterranean Sea (Scheinin *et al.,* 2011; Moore *et al.,* 2022; Nunny *et al.,* 2025). These movements coincide with a shift in prey preference toward pelagic amphipods like krill, possibly reflecting responses to declining quality and distribution of their traditional benthic prey (Moore *et al.,* 2022). While ecological flexibility may provide short-term resilience, it could also expose gray whales to new risks as moving into Out Of Habitat (OOH) areas and shifting to different prey types may increase vulnerability to both existing and novel threats (Nunny *et al.,* 2025).

Breeding grounds

All populations of gray whales are at a high risk from climatic changes due to their strong dependence on the west coast of Mexico for breeding.

Gray whale distributions can be significantly affected by El Niño and La Niña events: warmer El Niño periods have been associated with northward shifts, and cooler La Niña periods have been associated with southward shifts, especially within mother-calf pairings (Urbán *et al.,* 2003; Shelden *et al.,* 2004; Salvadeo *et al.,* 2015). These distribution shifts may be linked to changes in prey distributions, reducing thermal stress, and to optimise energy utilisation for newborns, calves, and mothers (Salvadeo *et al.,* 2015). Should the frequency and intensity of El Niño and La Niña events change as a result climate change (Calvin *et al*., 2023), then gray whale distribution over their breeding grounds may be impacted.

Migration

Gray whale migration between their feeding and breeding grounds is also impacted by climate change.

Changes in the timing of migrations have been inferred through patterns in calling activity in the Bering Strait region. Between 2012 and 2015 gray whale calling activity decreased in October/November but in 2016 this decrease was observed in September (Moore *et al.,* 2022). The earlier departure of gray whales from their feeding grounds has been linked to winter sea ice loss, suggesting that gray whales may leave foraging areas due to insufficient prey (Moore *et al.,* 2022). Observational data also suggest changes in the

timings of migrations, where there has been a one-week delay in southward migration (Rugh *et al.,* 2001). This delay in timing is thought to be due to the major oceanographic regime shift in the North Pacific Ocean in the 1970s (the central North Pacific warmed while the eastern part cooled, accompanied by stronger westerly winds and a deepening of the Aleutian low-pressure system), which resulted in a redistribution of whales on the feeding grounds (Rugh *et al.,* 2001). It has also been hypothesised that this may have caused northward relocation of the population, and subsequently that they would have to travel farther when migrating south (Rugh *et al.,* 2001). Thus, while the evidence varies, it is increasingly clear that gray whale phenology is changing in response to climate change.

Overall, climate change poses a severe and multifaceted threat to gray whales within their critical habitats (feeding and breeding grounds) and during their migrations. Climate change not only directly impacts their survival and population stability through rising temperatures and increased El Niño and La Niña events but also has the potential to intensifying existing pressures.

5.4 Welfare and conservation outcomes

Building on the impacts outlined above, climate change presents not only an ecological challenge but also a significant welfare concern for gray whales, with direct implications for the conservation of the species.

Drawing on observed impacts of climate change and guidance of the welfare assessment tool as a framework (Nicol *et al.,* 2020) *(Appendix Table 5),* the impact of climate change has been summarised in *Table 6* including potential welfare implications, conservation outcomes and mitigation strategies. It is important to note that impacts to welfare are a guided interpretation and not a direct assessment.

Table 6: Impacts of climate change on gray whale welfare and conservation, and potential mitigation strategies

Impacts of climate change	Effect on gray whale	Welfare implications	Conservation implications	Mitigation strategies

Increased temperatures	Distribution shifts in foraging grounds	Hunger, malnutrition, stress, increased energy expenditure, disruption to natural life cycles	Increased mortality, reduced body condition/length, reduced reproductive rates, increased conflict with human activities	New or updated protected areas and management plans that encompass the shift of critical areas/the temporal shift in migration corridors, management of anthropogenic activity (e.g. fisheries, oil and gas, renewable energies)
	Reduction/shift in prey			
	Migration temporal shifts			
	Migration spatial shifts			
Increase in El Niño and La Niña events	Distribution shifts in breeding grounds	Disruption of social behaviour, thermal shock, stress, pain, discomfort, increased energy expenditure	Increased mortality, reduced reproductive rates, increased conflict with human activities	New or updated protected areas and management plans that encompass the shift of critical areas, management of anthropogenic activity (e.g. fisheries, oil and gas, renewable energies)

5.5 Current conservation

Gray whales benefit from a range of conservation efforts at national and international levels (IWC, 2014; Marine Conservation Institute, 2024; Marine Mammal Commission, 2025). These include:

- The International Whaling Commission (IWC) working group on Anthropogenic Impacts in the Arctic Ocean Relevant to Cetaceans

- The Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) in the United States, which offers comprehensive protection from direct human harm
- Marine Protected Areas (effectiveness not assessed), designated around the breeding grounds of Baja California
- Long-term monitoring programs led by NOAA and research institutions (Gray whale research/Western Gray Whale Advisory Panel/The PCFG Consortium)

Although these frameworks provide some protection, the majority were not originally designed to address the emerging and complex threats posed by climate change. Therefore, several critical data and management gaps remain in relation to climate change:

- **Lack of overall population data**: The Western North Pacific (WNP) gray whale population remains significantly data-deficient compared to the Eastern population. This limits the ability to quantify climate-related threats and develop targeted conservation responses for specific populations.
- **Signs of population decline:** Gray whale population viability is declining due to climate change, yet no specific protection has been developed.
- **Anticipated changes and associated challenges:** Climate change will continue to shift habitat availability and migration patterns, with new areas of connectivity emerging, such as access to new habitat in an ice-free Arctic. These changes may expose gray whales to novel threats from human activities, increased competition between species, and increased predation (*Report of the Migratory Species and Climate Change Expert Workshop*, 2025). However, it is unknown if or how gray whales may adapt to climate stress, limiting the planning and effectiveness of conservation in regard to climate change.
- **Effectiveness of protection**: Gray whales benefit from several national and international conservation instruments and are indirectly protected through the designation of MPAs. However, these frameworks do not explicitly address the impacts of climate change, and the species is not prioritised in the planning or management of these areas. Additionally, these areas are static which can be a concern when species distributions and migrations shift resulting in MPAs not being effective.
- **Absence of welfare consideration**: Welfare considerations are largely missing from existing conservation plans, representing a significant gap in addressing the broader challenges the species faces.

Overall, despite existing conservation measures, current efforts remain insufficient in the face of the intensifying pressure of climate change. With the impacts of climate change expected to increase, more comprehensive and coordinated conservation strategies will be required to ensure the long-term survival of the species.

5.6 Potential actions

Recommendations for gray whale conservation in relation to climate change:

1. **Population and Threat Monitoring**
   - Continue and expand range-wide efforts to assess the distribution, abundance, and trends of gray whale populations to quantify the impacts of climate change.
   - Utilise robust process-based models for better understanding of ongoing changes and forecasting of future impacts of climate change. For example, due to gray whales' high dependency on prey availability, future models must incorporate environmental data, including prey interactions, to accurately predict how populations will respond to climate change (*Report of the Migratory Species and Climate Change Expert Workshop*, 2025).
   - Develop and implement the welfare assessment tool to evaluate the range of impacts of climate change on gray whale health and wellbeing.
   - Management of indirect, cumulative pressures (entanglement, overfishing of prey species, ship strike, regulating vessel activity in the Arctic/Russia, regulating tourism in Baja California etc.) to mitigate emerging threats arising from increased human–gray whale interactions as the species adapts to climate change.

2. **Habitat Management**
   - Identify and protect critical habitats in Arctic and Russian feeding grounds and Baja California breeding grounds that are essential for nutrition, calving, and reproduction.
   - Establish and protect critical sections of gray whale migration routes to maintain habitat connectivity (e.g. predictable and consistent sections, high abundance sections, conflict with human activity sections).

3. **Coordination and Capacity Building**
   - The gray whale is not currently listed on the CMS Appendices. Listing this species on the CMS appendices may support international cooperation and conservation measures, particularly in response to emerging threats such as climate change. However, most Parties that are Range States for the gray whale are not currently CMS Parties.
   - Enhanced international collaboration to promote sharing of data, monitoring methods, and management techniques will help to improve understanding of the population's response to climate change, and will increase protection across the gray whale's entire range.

- Create an international network of experts and stakeholders (scientists, communities, authorities such as Arctic council and International Maritime Organisation) to further support conservation actions.

6 Conclusions

There is clear evidence of the ecological impacts of climate change on the four case study species throughout the scientific literature. However, different cetacean species and populations exhibit varying levels of vulnerability to climate-driven changes. Impacts on species distributions and migrations have been well-documented but the direct, indirect and cumulative impacts of climate change and other pressures are poorly understood for most of the case study species. Thus, predicting the impacts of climate change remains challenging. Impacts on animal welfare are less well-documented, and this review suggests they are important to consider in conservation management. Impacts of climate change not only affect individual animals but can also have cascading effects on population viability and the effectiveness of current conservation efforts. Both should be brought into management decisions responding to climate change due to their link to conservation outcomes.

Despite existing protection measures for cetacean species, there remains a clear lack of targeted efforts addressing the intensifying pressure of climate change and its impacts on cetacean welfare and conservation. Given that climate change impacts are expected to increase in frequency and severity, conservation actions are urgently required to mitigate negative climate impacts and support cetaceans' adaptation to climate change.

7 Recommendations

Based on the literature reviewed and possible actions identified in the case studies from this report, as well as discussions documented in the report of the Migratory Species and Climate Change Expert Workshop (Edinburgh, February 2025), a set of recommendations have been developed. These recommendations aim to address the urgent challenges that climate change poses to cetacean welfare and conservation. Their implementation by CMS Parties, as well as non-Parties, has the potential to improve the protection of cetacean populations and habitats, ensuring the long-term health of cetaceans and marine ecosystems in response to the increasing pressure of climate change.

Recommendations:

- Prioritise conservation efforts towards vulnerable species and habitats most impacted by climate change (river basins, the Mediterranean Sea, the Black Sea and the Red Sea, and the Arctic region).
- Prioritise research efforts on climate change impacts on data deficient species.
- Aim to achieve long-term ecological monitoring of populations to provide baseline data and the ability to accurately quantify the pressure of climate change.
- Enhance methodologies for studying the impacts of climate change on cetaceans, such as advancing studies to capture cause-effect relationships.
- Conduct welfare assessments using the Welfare Assessment Tool for Wild Cetaceans to further quantify the impact of climate change on cetacean survival and help guide decision making.
- Incorporate early warning systems to help with quick responses and mitigation of catastrophic events related to climate change.
- Ensure adaptive protection by incorporating Important Marine Mammal Areas and/or updating existing Marine Protected Areas in response to climate-induced changes in cetacean spatial and temporal movement patterns, with particular focus on critical areas (feeding and breeding habitats) and key migration routes.
- Address indirect and cumulative impacts that exacerbate climate change effects to cetaceans (e.g. fisheries, shipping, coastal developments, resource exploitation, renewable energy, underwater noise, etc.).
- Enhance existing and new transboundary collaboration among international stakeholders (scientists, communities, authorities) by promoting the sharing of data and best practices related to the monitoring and management of cetaceans, facilitating a better understanding of the population level impacts of climate change.
- Improve efforts to mitigate climate change to minimize further climate change related impacts on cetaceans, such as promoting significant reductions in greenhouse gas emissions.
- Migratory cetacean species that are not currently listed on the CMS appendices but are threatened from climate change and could benefit from coordinated conservation efforts could be considered for listing on the CMS appendices.
- Encourage all countries that are Range States for CMS-listed cetaceans to accede to the Convention and/or proactively engage with CMS and other international conventions that support cetacean conservation.

8 Acknowledgements

The authors thank Vanesa Tossenberger (CMS COP-appointed Councillor for Aquatic Mammals), Mark Simmonds (CMS COP-appointed Councillor for Marine Pollution), Des

Thompson (CMS COP-appointed Councillor for Climate Change) and the Aquatic Species Team of the CMS Secretariat for their guidance in the preparation and review of this report, as well as Emily Martin (Joint Nature Conservation Committee) for supporting the production of the final draft. The authors also thank Fernando Trujillo, Robin Baird, Peter Evans, and Paul Thompson for their specialist input related to the species case studies, as well as Philippa Brakes and Rosie Williams for guidance related to welfare assessments and pollution impacts, respectively.

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10 Appendix

Table 1: Welfare Assessment Tool for Wild Cetaceans scoring sheet (Nicol et al., 2020).

Scenario	D1	D2	D3	D4	D5	Confidence (D1-D4)	Confidence (D5)	Impact duration	Event reoccurrence	Life span with some impact	Life span with moderate impact	Life span with severe impact	Life span with no/ minimal impact
Example: Impact of climate change on cetaceans	*1 = least harm to 10 = most harm*					*Low* *Medium* *High*	*Low* *Medium* *High*	*Days* *Weeks* *Months* *Years*	*1 = likely* *3 = very unlikely*	*%*	*%*	*%*	*%*

Table 2: The impacts of climate change on Amazon river dolphin categorised into the Welfare Assessment Tool (This is a guided interpretation and not a direct assessment) (Nicol et al., 2020).

Nutrition	Environment	Health	Behaviour	Mental state
Reduction of prey due to mass mortalities, altered spawning conditions, habitat connectivity, and ecosystem productivity	Increased temperatures Changes in flood pulse patterns Isolation in shallow waters Loss of habitat Declining water quality (pollution) Declining freshwater flow Increased salinity Increased sedimentation	Thermal shock Increased exposure to pollutants Increased exposure to disease Physical injuries from strandings	Disrupted social structures Increased human-dolphin conflict	Hunger, pain, discomfort, social loss, stress, etc.

Table 3: The impacts of climate change on common bottlenose dolphin categorised into the Welfare Assessment Tool (This is a guided interpretation and not a direct assessment) (Nicol et al., 2020).

Nutrition	Environment	Health	Behaviour	Mental state
Prey distribution shifts	Increased temperatures Declining water quality Toxic algal blooms	Increased exposure to disease Physical injuries from diseases Increased exposure to pollutants	Disrupted social structures Increased human-dolphin conflict	Hunger, pain, discomfort, social loss, stress, etc.

Table 4: The impacts of climate change on Cuvier's beaked whale categorised into the Welfare Assessment Tool (This is a guided interpretation and not a direct assessment) (Nicol et al., 2020).

Nutrition	Environment	Health	Behaviour	Mental state
Reduction and redistribution of prey	Increase frequency of El Niño and La Niña events	Vascular congestion Haemorrhages, gas bubble-associated lesions Fat emboli within vital organs Mortality events	Move to nearshore waters Increased dive duration Altered foraging behaviours Avoidance of anthropogenic noise	Hunger, pain, discomfort, stress, etc.

Table 5: The impacts of climate change on gray whales categorised into the Welfare Assessment Tool (This is a guided interpretation and not a direct assessment) (Nicol et al., 2020).

Nutrition	Environment	Health	Behaviour	Mental state
Reduction and change of prey due to dependency on sea ice	Increased temperatures Reduction of sea ice Increase frequency of El Niño and La Niña events Changes in feeding areas Changes in breeding areas	Decreased body condition Decrease reproduction Thematic shock	Changes in migration timings Increased human-whale conflict	Hunger, pain, discomfort, social loss, stress, etc.