Climate Change and Ocean Acidification – A Looming Crisis for Europe's Cetaceans

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> *"Without urgent and decisive action, the climate crisis will have dire welfare and conservation consequences for many of Europe's cetaceans."*
> Mark P. Simmonds

Introduction

Climate-related changes, including increased sea surface temperature (SST), decreasing ice cover, rising sea levels and changes in ocean circulation, salinity, rainfall patterns, storm frequency, wind speed, wave conditions and climate patterns are all affecting cetaceans (Learmonth *et al*., 2006; Silber *et al*., 2016). Additionally, an increase in the amount of carbon dioxide (CO_2) being absorbed by seawater is leading to ocean acidification, which – in turn- amplifies the adverse effects of global warming (Pace *et al*., 2015; IPCC, 2018).

Understanding the mechanisms through which climate change impacts any given species is a challenge, and scientists are increasingly focused on trying to predict consequences (Simmonds, 2016). The International Whaling Commission (IWC) has held a series of workshops about climate change and has highlighted the need to understand the relationship between cetacean distribution and measurable climatic indices such as SST (IWC, 2010).

The impacts of climate change on cetaceans can be direct, such as thermal stress, or indirect, such as changes in prey availability (Learmonth *et al*., 2006). Effects can lead to changes in distribution, abundance and migration patterns, the presence of competitors and/or predators, community structure, timing of breeding, reproductive success and survival. Other potential outcomes of climate change could be more dramatic, such as the exacerbation of epizootics (Simmonds, 2016). The incidence of harmful algal blooms may also increase as a result of climate change. The Scientific Committee of the IWC has recently looked at this topic and concluded that the toxins from the blooms have resulted in an increasing risk to cetacean health at the individual and population levels (IWC, 2018).

Human activities have caused approximately 1.0^{o}C of global warming above pre-industrial levels (IPCC, 2018) and it is estimated that global warming will reach 1.5^{o}C between 2030 and 2052. In the last 50 years the world's oceans have absorbed more than 90% of the excess heat in the climate system (IPCC, 2019). The rate of ocean warming has more than doubled since 1993 and marine heatwaves have become common and more intense.

Climate change and cetaceans in European waters

Much of the science looking at cetaceans and climate change has focused on Arctic species. Only some 10% of scientific papers published on this topic between 1997 and 2016 related to Europe (Nunny and Simmonds, 2016) and more recent articles tend to look north; for example, at the Norwegian Sea, the waters around Svalbard, and Iceland (e.g. Nøttestad *et al*., 2015; Víkingsson *et al*., 2015; Vacquié-Garcia *et al*., 2018). Nonetheless, there have also been studies focusing on North Atlantic and Mediterranean waters (e.g. Azzellino *et al*., 2008; Lambert *et al*., 2014; Cañadas and Vázquez, 2017; Sousa *et al*., 2019).

In Europe the increase in SSTs has been more rapid than the global average (Reid, 2016). In northerly waters there have been elevated sub-surface temperatures in the Norwegian Sea (Nøttestad *et al*., 2015) and waters around Svalbard have been warming, contributing to a decline in sea ice (Descamps *et al*., 2017). Sea temperature and salinity have also increased in Icelandic waters (Víkingsson *et al*., 2015). Across the UK continental shelf, SSTs have been increasing over the last 30 years with warming the strongest in the North Atlantic north of 60^{o}N and the fastest rate of warming off the east coast of Iceland (Tinker and Howes, 2020). Significant SST increases have been recorded North of Scotland and in most of the North Sea of up to 0.24^{o}C per decade.

In the Western Mediterranean the average annual maximum temperature for 2002 – 2006 was 1^{o}C above the mean maximum temperature (MMT) of 26.6^{o}C for 1988-1999 (Marbà and Duarte, 2010). Warming of SST in the Mediterranean in recent decades is due in part to anthropogenic-caused climate change combined with the positive phase of a natural oscillation in temperature called the Atlantic Multidecadal Oscillation (AMO) (Macias *et al*., 2013). A recent slowdown in warming in this region is probably due to a shift in the AMO phase, which may mask warming effects in the coming decades in the Mediterranean and adjacent waters.

Indeed, some sea areas have even seen a cooling in ocean temperatures, for example in the area known as the 'Big Blue Blob' in the North Atlantic. This is a phenomenon which started in 2013 and recorded its lowest temperature in 2015 (Tinker and Howes, 2020). This has also meant that the UK's south-west coast, for example, has not warmed significantly in recent years.

Since 1987, the abundance of humpback whales (*Megaptera novaeangliae*) and fin whales (*Balaenoptera physalus*) in Icelandic waters has increased and the abundance of minke whales (*Balaenoptera acutorostrata*) on the Icelandic continental shelf has decreased (Víkingsson *et al*., 2015). Blue whale (*Balaenoptera musculus*) distribution has also altered with a shift northwards. In the North Atlantic, models have predicted that species that favour warmer waters (e.g. striped dolphin (*Stenella coeruleoalba*)) will expand northwards and that cooler water species (minke whale, northern bottlenose whale (*Hyperoodon ampullatus*) and white-beaked dolphin (*Lagenorhynchus albirostris*)) will contract their range northwards (Lambert *et al*., 2014). A collation of survey data from 1986-2016 covering the North-West European continental shelf from south-west Norway to Portugal revealed that white-beaked dolphins and Atlantic white-sided dolphins (*Lagenorhynchus acutus*), species which have cold temperate to low-arctic ranges, have decreased in abundance whereas short-beaked common dolphins (*Delphinus delphis*) and striped dolphins (species which have warm temperate ranges) have increased (Evans and Waggitt, 2020).

Anthropogenic CO_2 concentration in the Mediterranean is relatively high and acidification has been detected (Pace *et al*., 2015; Lacoue-Labarthe *et al*., 2016). Combined with rising temperatures, acidification may impact cetaceans by affecting the availability of their prey (Pace *et al*., 2015; Lacoue-Labarthe *et al*., 2016). Long-finned pilot whale (*Globicephala melas*) distribution and population structure in the Mediterranean may be affected as some of their prey, e.g. squid, is sensitive to temperature and ocean acidification (Verborgh *et al*., 2016). Ocean acidification in the Mediterranean will affect the trophic web in a number of ways such as a reduction in productivity of seagrass (*Posidonia oceanica*), and impacts on productivity and biodiversity of phytoplankton and zooplankton (Lacoue-Labarthe *et al*., 2016). These changes will, in turn, affect higher levels of the food web. Deoxygenation of the ocean due to warming is another threat and could be a particular problem in enclosed areas such as the Black and Baltic Seas (Reid, 2016).

Ability to adapt

Some cetaceans may be able to adapt to climate change-driven alterations to some, as yet unknown, extent (Simmonds, 2017a). For example, as macro-zooplankton becomes less available because of higher temperatures in the Norwegian Sea, fin whales and minke whales have adapted their feeding to focus more on pelagic fish such as Norwegian spring-spawning herring (*Clupea harengus*) (Nøttestad *et al*., 2015).

Belugas (*Delphinapterus leucas*) in Svalbard continue to use glacier fronts as foraging areas but, following the decline in sea ice, have recently started to spend more time in the fjords of west Spitsbergen during summer and autumn (Vacquié-Garcia *et al*., 2018). This suggests a change in diet, or at least a broadening of their diet, as they start to feed more on Atlantic fish species which are arriving in the fjords with warmer Atlantic water (Vacquié-Garcia *et al*., 2018). Similarly, in Icelandic waters, changes in sea temperature and salinity have been accompanied by a change in the distribution of a number of fish and krill species and the distributions and abundance of several cetacean species (Víkingsson *et al*., 2015).

Inability to adapt and loss of habitat

Some cetaceans, such as those which inhabit continental shelf areas, may find that continued changes in temperature and/or prey availability make their home areas inhospitable (Simmonds, 2017a). McLeod *et al*. (2008) anticipated that white-beaked dolphins living in shelf waters off the United Kingdom and Ireland would experience a loss of habitat. Indeed the abundance of this species in Europe shows a strong negative relationship to increasing temperature (Evans and Waggitt, 2020). Lambert *et al*. (2014) have predicted that, by 2060, their habitat will have been reduced by 80% in this region (in medium or high emission scenarios).

Another species that may lose habitat is the minke whale. It has been predicted that the southern part of the North Atlantic minke whale's range will see a reduction in suitable habitat and feeding opportunities by the 2080s (in medium and high emission scenarios) (Lambert *et al*., 2014). Beaked whales which rely on deep sea trenches may be especially vulnerable (Simmonds, 2016) as may the cetaceans that live in enclosed areas such as the three delphinid species resident in the Black Sea (short-beaked common dolphin (*Delphinus delphis ponticus*), Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) and Black Sea harbour porpoise (*Phocoena phocoena relicta*)) (Simmonds, 2017a).

Sousa *et al*. (2019) assessed seven cetacean species around Madeira and found that the sperm whale (*Physeter macrocephalus*) is likely the most vulnerable, followed by the fin whale, bottlenose dolphin (*Tursiops truncatus*) and Bryde's whale (*Balaenoptera edeni*). Sperm whales were found to be particularly vulnerable because of their low genetic variability and diet diversity, their vulnerable status and because of their migratory behaviour (Sousa *et al*., 2019).

In the Ligurian Sea, fin whales, striped dolphins and sperm whale distributions may alter in response to climate change (Azzellino *et al*., 2008). Likewise, a rise in SST in the Alboran Sea is predicted to reduce the suitable habitat available for local common dolphins, a subpopulation already listed as endangered by the IUCN (International Union for Conservation of Nature) (Cañadas and Vázquez, 2017).

Biological timing issues

Many cetaceans are migratory, ranging from bigger species that regularly oscillate between polar feeding grounds and warm breeding grounds to smaller species that regularly move between inshore and offshore areas. The animals need to find certain conditions for their survival and the timing of migrations allows exploitation of resources such as the spring bloom of prey in the Arctic. However, climate change may affect the timing of key phenomena causing whales to arrive out of sync with the resources they seek (Simmonds and Elliott, 2009). In the Norwegian Sea some shifts in the distribution and abundance patterns of cetaceans have recently been linked to changing levels of abundance in their prey and elevated SSTs (Nøttestad *et al*., 2015). Similar plasticity in behaviour has been suggested for fin whales in the Mediterranean (Notarbartolo di Sciara *et al*., 2016). However, the extent that populations will be able to respond to changing conditions is unknown.

Human behaviour, welfare and synergies

Climate change will cause humans to alter some of their behaviours, in turn impacting cetaceans (Simmonds, 2017a). For example, if humans become more reliant on marine species as food, cetaceans may find themselves facing increased prey depletion and bycatch or even being taken directly (Alter *et al*., 2010). Potential increases in aquaculture could lead to local eutrophication and conflict with local marine mammals. Other human-mediated effects might include:

- increased shipping;
- more coastal construction work;
- increased exposure to pollution and pathogens; and
- an increase in disasters such as oil spills as vessels move into new areas (Simmonds, 2017a; Alter *et al*., 2010).

Welfare will also be impaired if individual cetaceans find their ability to feed and reproduce is impacted or their health otherwise compromised and climate-driven changes will act synergistically with other stressors, including ocean acidification, pollution (including PCBs (persistent polychlorinated biphenyls)) and other threats (Simmonds, 2017b; Jepson *et al*., 2016). Figure 1 shows some of the interacting variables and the link between welfare at the individual level and conservation of the population.

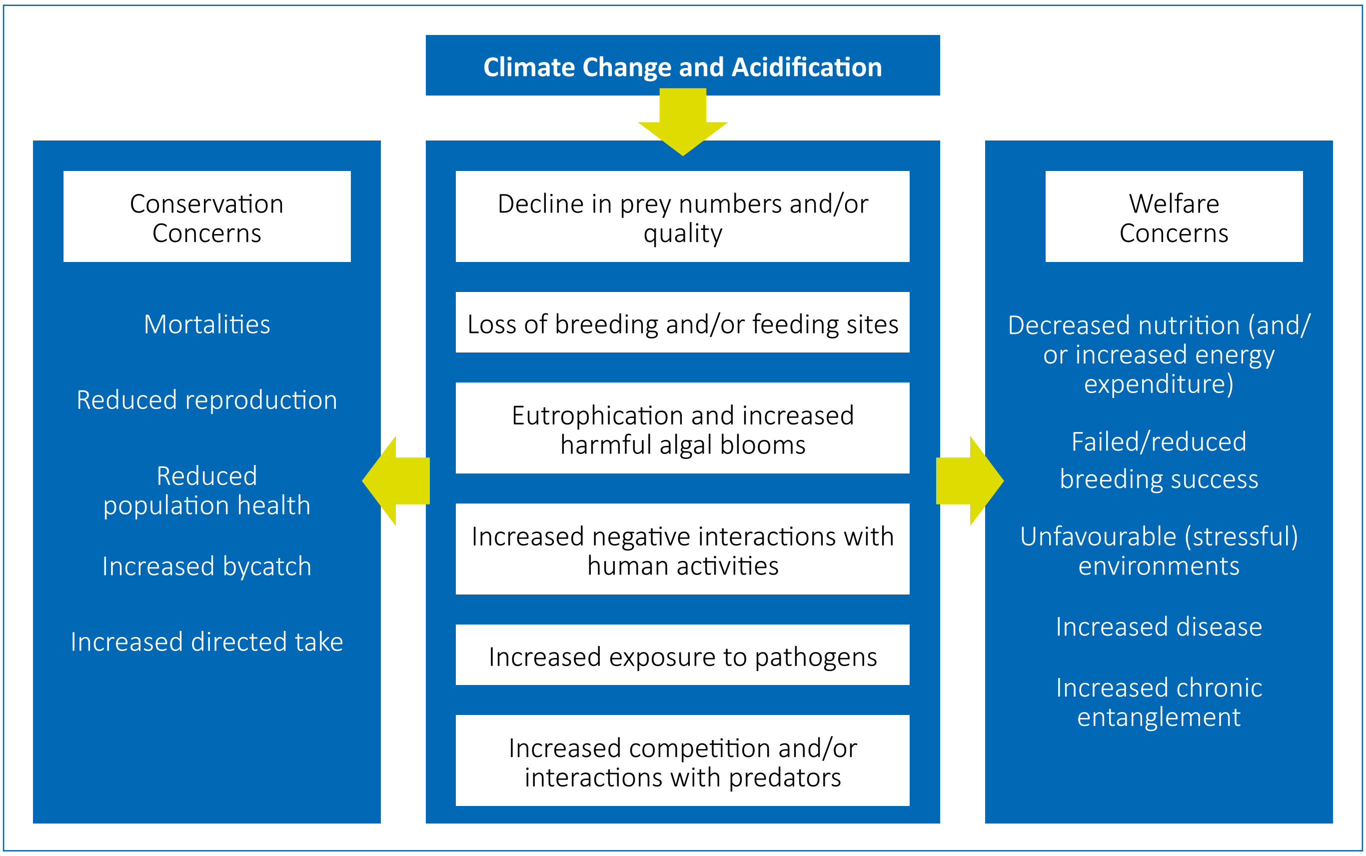

Figure 1: Examples of the cetacean conservation and welfare concerns that may be driven by climate change and acidification.

Indeed, how cetaceans are impacted by climate change needs to be considered alongside other threats to their health and wellbeing. For example, Jepson *et al*. (2016) reported that certain European cetaceans are particularly at risk from PCBs contamination. The resulting immunosuppression and reproductive failure which this contamination can produce, when combined with changes in the marine environment due to climate change, may make some cetaceans more susceptible to disease (Simmonds, 2016; Simmonds, 2017b; Jepson *et al*., 2016).

Conclusion

Climate change and ocean acidification can already be seen to be having an impact on European marine systems and some European cetacean species. Urgent action is needed to limit the negative welfare and conservation consequences that the climate crisis will cause for the cetaceans living in the cold temperate water habitats of Europe. Those limited to enclosed waters, and less able to move away from adverse changes, may be especially vulnerable.

Recommended actions

Policy

- Urgently address other non-climate threats to cetacean populations to take pressure off them.
- Use the precautionary approach in conservation policy and educate the public about how climate change can impact cetaceans.
- Meet targets to reduce CO_2 and other relevant emissions.

Management measures

- Introduce larger protected marine areas, potentially with flexible or mobile boundaries to take into account the fact that changes in their habitat may prompt cetaceans to move outside of established habitat areas.

Private sector

- Reduce consumption of fossil fuels that contribute to CO_2 production and climate change.
- Invest in green energy.

Science

- Continue comprehensive monitoring of cetaceans in European waters including health studies.
- Use models to predict impacts of climate change on different species/populations in different locations and so inform conservation actions.

Public

- Reduce dependence on and consumption of fossil fuels.
- Reduce consumption of meat and other animal products which cause the emission of greenhouse gases.
- Buy local produce to reduce "food miles".

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