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Marine Mammals

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EXECUTIVE SUMMARY

- The impact of climate change on marine mammals remains poorly understood. As a result, there has been a great deal of speculation but without very much substantive evidence. That evidence for marine mammals is very difficult to obtain, particularly when there are often synergistic effects from anthropogenic activities.
- Most obvious impacts are loss of available habitat such as ice cover to ice-breeding pinnipeds. This already is thought to affect ringed seals and their main predator, the polar bear, in arctic regions.
- In more temperate regions, environmental changes will likely be reflected mainly in responses to changes in prey abundance and distribution as a result of warmer sea temperatures, and enhanced stratification forcing earlier occurrence of the spring phytoplankton bloom and potential cascading effects through the food chain. There may also be effects through changes in the locations of fronts and water masses, and overall reduced primary and secondary plankton production.
- Range shifts can be observed in a number of odontocete cetacean species, and these have been linked to increasing sea temperatures. However, the mechanisms causing those changes remain uncertain, and for some species, it is difficult to differentiate between short-term responses to regional resource variability and longer-term ones driven by climate change.
- NW European species likely to be most affected in the future will be those that have relatively narrow habitat requirements – shelf sea species like the harbour porpoise, white-beaked dolphin and minke whale may come under increased pressure with reduced available habitat if they experience range shifts northwards. If overall secondary production is reduced, this could directly affect some baleen whale species that feed upon zooplankton, as well as have indirect effects on fish and cephalopod feeders.

FULL REVIEW

Overview

Marine mammals are warm-blooded thermo-regulating vertebrates with both physiological and behavioural mechanisms developed to respond readily to changes in their external environment. This means they might be expected to cope well with most environmental variance predicted from climate change. They are known to employ complex behavioural adaptation that can lead to them having strong buffering against environmental variability, including variation in food supply. These adaptations can extend to life-history processes, some of which are sensitive to temperature, especially with respect to the thermoregulation of neonates. On the other hand, we would anticipate changes in the availability of their habitat (including food resources) to lead to changes in population size or distribution in particular cases. The most obvious example in this context is the reduction in ice cover affecting ice-breeding polar seals such as the walrus, bearded, hooded, ribbon, harp and ringed seal, and its consequent effect upon predators like the polar bear (Stirling *et al*., 1999; Derocher *et al*., 2004; Ferguson *et al*., 2005; Huntington & Moore, 2008).

Of cetaceans in the northern hemisphere, narwhal, beluga and bowhead whale are likely to be most affected, but temperature changes may also affect cold-water shelf species occurring in Northern Europe like the harbour porpoise and white-beaked dolphin (Laidre *et al*., 2008; Huntington & Moore, 2008; IWC, 2009; MacLeod, 2009). Other physical changes to the habitat include increased sea levels modifying shallow seas. These could affect the hydrodynamics and physiography of breeding bays & lagoons of coastal species like the grey whale (IWC, 1997, 2009), and the availability of protected caves for breeding seals, as well as low-lying areas and other haul-out sites (e.g. the endangered Mediterranean monk seal – Harwood, 2001).

Other vulnerable species include dugongs and manatees, humpback dolphins, tucuxi, and finless porpoise all of whose diets appear to depend upon shallow-water species (sea grasses in the case of sirenians – see Short & Neckles, 1999; and fishes and invertebrates in the case of those cetacean species (Würsig *et al*., 2002; Learmonth *et al*., 2006). With rising sea levels, many of the shallow areas (for example in the Western Pacific) will be lost. However, in the UK, those conditions are not likely to be important at least in the foreseeable future.

1. What is already happening?

Recent warming of the seas around the British Isles has coincided with a northward shift in the distribution of zooplankton (Beaugrand *et al*., 2002; Reid *et al*., 2003) and fish species (Beare *et al*., 2004; Perry *et al*., 2005; Cheung *et al*., 2009). Those changes are most evident near the northern or southern boundaries of the species range (Rose, 2005). The same appears to be the case for certain cetacean species, with the typical warmer water dolphins – short-beaked common dolphin and striped dolphin, apparently recently extending their shelf sea range further north off western Britain and around into the northern North Sea (Evans *et al*., 2003; MacLeod *et al*., 2005). Common dolphins are now seen quite regularly in the North Sea even in winter (Sea Watch Foundation, unpubl. data), and this may reflect the expanding range of typically warmer water fish species like anchovy and sardine (Brander *et al*., 2003; ICES, 2008). Other warm water species recorded for the first time in the UK in recent years include Blainville's beaked whale (1993) and Fraser's dolphin (1996), whilst ten out of eleven strandings of pygmy sperm whale in Britain & Ireland have occurred since 1980 (Evans *et al*., 2003; CSIP unpubl. data), and between January and April 2008, there were 18 strandings of another typically warm water species, the Cuvier's beaked whale, in Wales, Scotland, and Ireland (Dolman *et al*., 2010). Although these strandings may not be directly related to climate change, they occurred much further north than would be expected for this species. Nevertheless, at this stage, it is unwise to draw too many conclusions from records of vagrants.

The ability to detect long-term trends in cetaceans around the UK is limited by the paucity of effort-based sightings data before 1980. The recent multiple presence of short-beaked common dolphin schools in the northern North Sea is not entirely new, for example. There have been both strandings and sightings in that region during the 1980s (Sheldrick, 1989; Baines *et al*., 2006), and a marked peak in UK North Sea strandings was reported during the 1930s (Fraser, 1946), and along the Dutch coast in the 1940s (Bakker & Smeenk, 1987; Camphuysen & Peet, 2007). These patterns in strandings may reflect decadal climatic cycles such as caused by the North Atlantic Oscillation (which was in a positive phase during those periods, characterised by stronger westerly winds, higher sea temperatures, and milder winters with wetter and stormier conditions (Hulme *et al*., 2002).

Another species reported to have recently exhibited range shifts is the white-beaked dolphin, a species of largely cold temperate to arctic waters (Evans *et al*., 2003; MacLeod *et al.*, 2005, 2007c; Baines *et al*., 2006; Evans & Smeenk, 2008). Although these may not necessarily be directly related to sea temperature changes but simply reflect changes in the status of particular fish stocks that are favoured prey of the species, there have been shifts in regional distribution for this and other species. Stranding records have shown a significant increase of the white-beaked dolphin in the southern North Sea since the 1960s, and the species now regularly occurs in the Southern Bight (Bakker & Smeenk, 1987; Kinze *et al.*, 1997; Camphuysen & Peet, 2007). This emphasises the difficulties in interpreting regional changes in status, not only because there are many potential confounding effects (not least being human over-exploitation of fish or squid stocks) but also because those marine mammal species may simply be responding to regional variability in resource availability independent of climate change.

Amongst marine mammals, information on population trends, breeding success and feeding ecology is most prevalent for seals. Whilst the evidence for climate change effects upon cetaceans in UK waters remains equivocal, there is no evidence as yet that climate change has directly affected either of the two UK breeding seal species (grey and harbour seal), although elsewhere in the world, several authors have attempted to link changes in seal population dynamics and life history parameters to climate change (see, for example, Sun *et al*., 2004; McMahon & Burton, 2005; Forcada *et al*., 2005). It is possible that recent demographic changes (increases in most grey seal populations and declines in some harbour seal populations) are linked in some way to climate-mediated changes in food supply, although other factors (depletion of food resources from fishing, recovery from epizootics, interspecific competition, density dependent effects) may be more important (SCOS, 2008).

2. What could happen in the future?

Responses both at the individual and population level of marine mammal species to climate change are poorly understood. Making predictions about future impacts becomes even more speculative. In the last 15 years, a number of marine mammal scientists have attempted to do this (Tynan & DeMaster, 1997; IWC, 1997, 2009; Würsig *et al*., 2002; Learmonth *et al*., 2006; Simmonds & Isaac, 2007; Huntington & Moore, 2008; Laidre *et al*., 2008; MacLeod, 2009). The main potential impacts are summarised under the following headings:

Range shifts: As a result of increased sea temperatures, it is thought that species will shift their ranges to remain within their preferred thermal habitats (Simmonds & Elliott, 2008; MacLeod, 2009). This may not necessarily result in a negative response, although species with restricted distributions such as the vaquita, river dolphins, bowhead whale, narwhal, and polar seals, may be unable to change their geographic range (Tynan & DeMaster, 1997; IWC, 1997; Huntington & Moore, 2008). It has been suggested that a major impact of climate change will be a redistribution of cetacean species diversity from tropical regions to mid latitudes (Whitehead *et al*., 2008).

In the UK, one might expect species like the short-beaked common and striped dolphin to occur more regularly in northern Britain and within the North Sea, displacing the white-beaked and Atlantic white–sided dolphin. The white-beaked dolphin favours shelf habitats and so may be placed under increased pressure if it loses the North-west European continental shelf within its range. Likewise, other shelf species, the harbour porpoise and minke whale, could move northwards. On the other hand, Cuvier's beaked whale may become more regular in offshore Atlantic canyons such as the Porcupine Bight west of Ireland and the Rockall Trough west of Scotland - potentially suitable habitat for the species (Evans *et al*., 2008). There could also be more records of warm-water vagrants to north-west Europe (e.g. Bryde's whale, pygmy sperm whale, rough-toothed dolphin, and Atlantic spotted dolphin). Baleen whales (e.g. humpback whale) that move southwards to warmer waters to winter where they breed, may increasingly do so within UK waters.

Changes to physical habitat: The melting of sea ice clearly poses a threat to those marine mammals (such as seals) that use it for hauling out or breeding, as well as to their predators (Harwood, 2001; Derocher *et al*., 2004; Ferguson *et al*., 2005). Changes to open water refugia in the ice may affect species like beluga and narwhal (Heide-Jørgensen & Laidre, 2004; Laidre & Heide-Jørgensen, 2005). Rising sea levels may affect shallow water species such as tucuxi, humpback dolphin, and finless porpoise, as well as those species such as the grey whale, calving in shallow coastal bays (IWC, 1997, 2009; Würsig *et al*., 2002). In the UK, however, it is unlikely that changes to the physical habitat will affect cetaceans, although some seal haul-out / breeding locations in caves or on low lying coasts (e.g. in particular, parts of The Wash for harbour seals, but possibly also the Monach Isles on the Scottish continental shelf for grey seals, and the Dornoch Firth for both species) may be lost or modified. Increases in storm frequency and associated wave surges could exacerbate effects.

There is some evidence that changes in rainfall patterns might affect the breeding behaviour of grey seals. Increased rainfall, for example, can increase the availability of pools in some breeding colonies. Females aggregate around pools, thus enabling a small number of males to monopolise access to females as they enter oestrus (Twiss *et al*., 2007). Conversely, in dry conditions, females disperse more widely, providing additional males with the opportunity to mate. Increased rainfall and severe weather may also increase pup mortality at breeding sites. However, seals may adapt to a number of these changes, and new habitats may be created.

Ocean acidification is predicted to affect water chemistry by reducing the ability to absorb atmospheric carbon dioxide (Ocean Acidification Reference User Group, 2009). Besides direct effects upon marine organisms with calcium carbonate skeletons or shells, some of which form prey to marine mammals (see next section), a more acidic ocean is likely to be a noisier one, since low and mid frequency sounds in particular will be less absorbed. By 2050, under conservative projections of ocean acidification, sounds could travel as much as 70% farther in some ocean areas (particularly in the Atlantic Ocean) (Hester *et al*., 2008). Whereas this may greatly improve the ability of baleen whales to communicate with one another over long distances, it could also increase the amount of background noise generated, for example from seismic activity (Hester *et al*., 2008).

Changes to the food web: Effects of changes to community structure are probably the most difficult to predict. Changes in ocean currents and the positions of associated fronts as well as in ocean mixing, deep water production and coastal upwellings could have profound effects on biological productivity (Walther *et al*., 2002; Stenseth *et al*., 2002, 2004), which in turn is likely to affect top predators such as marine mammals (IWC, 1999, 2009; Bjørge, 2002; Würsig *et al*., 2002; Huntington & Moore, 2008; Nicol *et al*., 2008). A reduction in ocean productivity over the past decade has been driven largely by the warming and stratification of lower latitude waters, blocking the nutrients necessary for phytoplankton growth (Behrenfeld *et al*., 2006). Enhanced stratification also forces earlier occurrence of the spring phytoplankton bloom and potential cascading effects through the food chain. Reduced zooplankton abundance is likely to affect baleen whales, particularly those with restricted diets such as right whales which feed largely upon copepod aggregations (Greene & Pershing, 2004; Leaper *et al*., 2005; Kenney, 2007), thus inhibiting possible recovery of the species in the eastern North Atlantic. On the other hand, increasing storm events could deepen the mixed layer and thereby increase nutrient availability in the upper ocean and ultimately enhance production of marine mammal prey. In most cases it is hard to determine how exactly these changes will impact particular marine mammal species (Trites *et al*., 2006; Moore, 2009).

More complicated scenarios include mismatches in synchrony between predator and prey, either in time or location (Edwards & Richardson, 2004; Durant *et al*., 2007). This uncoupling of phenological relationships at different trophic levels is thought to have been responsible for recent failures in sandeel recruitment in the North Sea with high winter temperatures negatively affecting early larval survival (Arnott & Ruxton, 2002; Van Deurs *et al*., 2009) and consequent breeding failures amongst several UK seabird species largely dependent on sandeels (Rindorf *et al*., 2000; Frederiksen *et al*., 2004, 2005; Wanless *et al*., 2005; Mavor *et al*., 2006). There has been some speculation that the recent shift in abundance of harbour porpoises from the northern to southern North Sea may be due to a shortage of sandeels, a known prey item, Low abundance of sandeels could be related to poor body condition amongst stranded porpoises in the Scottish North Sea (MacLeod *et al*., 2007a, b; but see Thompson *et al*., 2007). On the other hand, if these observations do indeed reflect a real change, it may also be due to other prey-related changes such as the recovery of some herring stocks in the southern North Sea. At present, we have little idea to what extent species like the harbour porpoise have particular dietary preferences although high-energy shoaling fish such as herring, sprat and sandeel often form important components of porpoise diet (Santos *et al*., 2004; Pierce *et al*., 2007; Evans *et al*., 2008).

A number of findings indicating potential effects on other marine taxa could also impact upon marine mammals through the food chain. Examples include reductions in salinity due to increased freshwater inputs, increases in CO_2 and consequent increased acidification (IPCC, 2007) particularly affecting cephalopods (Boyle, 1983; Pörtner *et al*., 2004; Royal Society, 2005). Changes in CO_2 levels and pH are likely to affect metabolic function and thus growth and reproduction (Pörtner *et al*., 2004; Royal Society, 2005). Sensitivity is highest in ommastrephid squids, such as *Illex illecebrosus*, which are characterised by a high metabolic rate and extremely pH-sensitive blood oxygen transportation (Boyle, 1983). Several marine mammal species feed either exclusively or to a large extent upon cephalopods.

Squid have increased in abundance in recent years in the Western Approaches, Channel, and North Sea (J. Van Der Kooij, *pers. comm.*) which in turn may lead to increased presence in these waters of squid predators such as Risso's dolphin, striped dolphin, sperm whale and species of beaked whales, in those areas where suitable habitat exists.

Susceptibility to disease and contaminants: Global warming has been implicated in the worldwide increase in reports of diseases affecting marine organisms, including marine mammals (Harvell *et al*., 2002; Geraci & Lounsbury, 2002; Lafferty *et al*., 2004; Van Bressem *et al*., 2009). Climate change has the potential to increase pathogen development and survival rates, disease transmission, and host susceptibility (Harvell *et al*., 2002), whilst higher temperatures may stress organisms, increasing their susceptibility to some diseases (Lafferty *et al*., 2004). Subtle effects of pollutants (e.g. disruption of the immune, reproductive or endocrine systems) could also be exacerbated by nutritional stress (Jepson *et al*., 2005; Hall *et al*., 2006).

The frequency and severity of toxic algal blooms (i.e. those producing domoic acid) are also predicted to increase as a result of nutrient enrichment (increased rainfall and freshwater runoff), increased temperature and salinity (Peperzak, 2003; Lafferty *et al*., 2004), and indeed there is some evidence that they have already (Van Dolah, 2000). Mass die-offs due to fatal poisonings have been reported in several marine mammal species (Geraci *et al*., 1999; Domingo *et al*., 2002; Geraci & Lounsbury, 2002), for example Mediterranean monk seals (Hernández *et al*., 1998), California sea lions (Scholin *et al*., 2000), bottlenose dolphins (Fire *et al*., 2007, 2008), and Florida manatees (Bossart *et al*., 1998). They may also be responsible for increased calf mortality amongst Patagonian right whales (IWC, 2009).

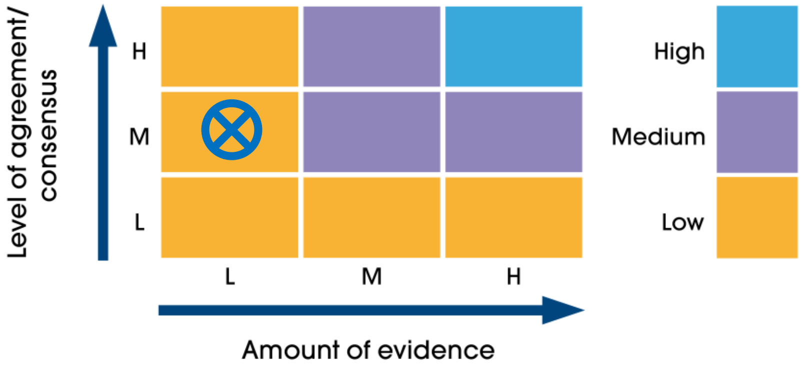
The effects of pollutants as added stressors to predators already suffering from changes in habitat and prey availability, remains poorly understood (IWC, 2009). There are some suggestions that climatic warming, causing changes in temperature, precipitation, and weather patterns, will alter the pathways (e.g. persistence), and concentrations of pollutants entering more pristine regions via long-range transport on air and ocean currents (MacDonald *et al*., 2005).

Thermal Intolerance: There are few direct data about thermal tolerances in marine mammals. Those species or populations that inhabit polar seas tend to have thicker blubber layers. Good examples are the bowhead whale, and other baleen whales when on summer feeding grounds at high latitudes. It has been suggested that except perhaps for the smallest species like the harbour porpoise, hypothermia is not so much an issue as the possibility of heat stress (hyperthermia) in warmer waters (Hokkanen, 1990). However, this has rarely been directly explored, and it is unclear how widely the generalisation holds. In their present calving grounds off the coasts of Georgia and northern Florida, northern right whales appear to select cooler water (Kraus *et al*., 1993; Ward, 1999), and it has been postulated that warming sea temperatures may subject the species to thermal stress and associated negative impacts forcing the species to shift its winter calving grounds northwards, reoccupying historical calving grounds that are no longer used (Kenney, 2007). The possibility of a negative effect will then likely depend on whether in those areas there is increased risk of ship strikes or fishing gear entanglement, both of which are currently important causes of mortality for the species (Kraus & Rolland, 2007). Nevertheless, at this stage, the extent to which marine mammals are constrained thermally, if at all, is poorly known, as are any possible consequences.

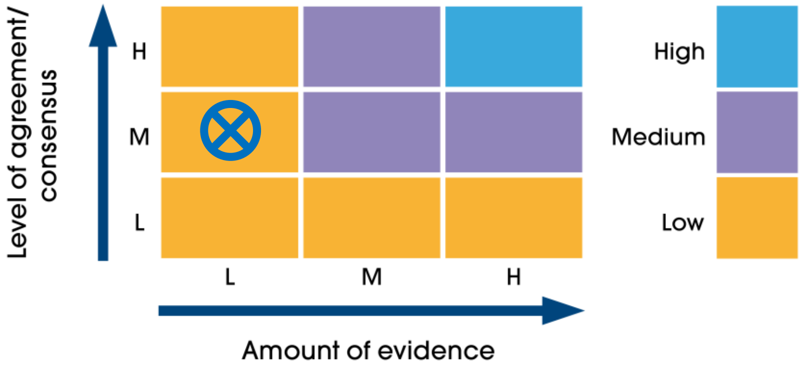
As yet, most of the above predictions are still somewhat speculative and often unsubstantiated by unequivocal evidence. This reflects the difficulties in studying marine mammals, using experimental approaches to test hypotheses, and disentangling various potential confounding variables.

3. Confidence in the science

What is already happening: **Low**



What could happen: **Low**



Range shifts for particular species, reported in the 2007-08 Report Card, have persisted to the present. Research on climate change effects upon marine mammals has also expanded in recent years both in Europe and elsewhere, whilst there have been a number of meetings/workshops addressing this issue with respect to marine mammals (ICES WGMME, 2007; IWC, 2009; ECS, 2009), as well as a Special Publication of the journal *Ecological Applications* focusing upon Arctic Marine Mammals and Climate Change (2008).

4. Knowledge gaps

The top priority knowledge gaps, that need to be addressed in the short term to provide better advice to be given to policy makers, are:

1. A pre-requisite to assessing impacts of climate change on marine mammals at a population level is a long-term, wide-ranging, monitoring programme that can discriminate between regional population responses and those occurring on a wider geographical scale. This is presently lacking for all UK cetacean species, whilst for seals there remain regions (e.g. Irish Sea) with only patchy coverage.

2. Our knowledge of trends in basic life history parameters (growth rates, age at sexual maturity, reproductive rates, and mortality) for all cetacean species with the possible exception of harbour porpoise is woefully inadequate, based

upon small sample sizes from a restricted number of areas, and without long-term continuity of data. For the majority of species, we are unlikely to obtain adequate information in the foreseeable future given how difficult they are to study and the resources available to do so. However, certain species could be targeted for more intensive study with some likelihood of success. In UK waters, these include (in addition to harbour porpoise) bottlenose dolphin, short-beaked common dolphin, white-beaked dolphin, Risso's dolphin, and minke whale. In particular, two long-term studies exist on coastal populations of bottlenose dolphins – Moray Firth (20 years) and Cardigan Bay (10 years), which could serve to provide a better understanding of the interaction between climate-mediated changes in the environment and changes in distribution, habitat use and demography.

3. Functional responses to environmental change through physiological and behavioural mechanisms are also poorly understood for most marine mammal species. For this, seals are rather better suited to experimental studies where variables can be controlled. However, it is unclear whether data from seals can be generalised to cetaceans due to ecological differences between the two groups. Once individual responses are better understood, it may be possible to make predictions at the population level, but it will be necessary to conduct these studies across both seals and cetaceans.
4. Too little is known about how changes in fish, cephalopod and plankton dispersion, distribution and abundance may affect the foraging ecology of particular marine mammal species. Often, one of the major gaps in information lies in the lack of data for non-commercial fish and cephalopod species, although even for some commercial species, such information is lacking.
5. There is a need for better understanding of how predictions from climate models relate to changes most likely to impact upon marine mammals. Overall rises in sea temperatures, for example, need to be separated from changes in the timing and location of fronts, and in turn how these may affect prey resources (abundance, distribution, and availability) and the energetics of different marine mammal predators.
6. Models have routinely been used on marine mammal populations to better understand population dynamics and to forecast the implications of anthropogenic impacts. However, they generally face the limitations of inadequate real data, a poor understanding of mechanisms, and an inability to model those mechanisms adequately. On the other hand, they can be useful to compare alternative scenarios and hence to identify specific data gaps that if filled are most likely to allow discrimination between scenarios. Priority should be given to developing models that can integrate the demographic and spatial consequences of climate change, as well as developing full ecosystem models using top-down as well as bottom-up approaches.

5. Socio-economic impacts

No marine mammal species in UK is exploited directly. However, changes in the status and distribution of marine mammals could potentially have commercial effects if species (e.g. minke whale, bottlenose dolphin) targeted by the ecotourism industry become scarce, or there are changes in competitive relations (e.g. an increase in seal predation upon commercially important fish).

If climate change affects human behaviour, for example by increased pressure on already depleted fish stocks or shifts to squid fisheries, those in turn could affect marine mammal species through their food supply. If there is increased usage of the coastal zone for particular human activities (e.g. recreation), these could impose pressures through disturbance and pollution. A greater emphasis upon offshore renewable energy sources such as wind and tide may result in increased conflicts with marine mammal species like the harbour porpoise, bottlenose dolphin, minke whale, and harbour seal, that often forage in coastal areas and within high energy sites around headlands and island archipelagos. Negative effects include sound disturbance particularly during pile driving construction activities in the case of wind farms or potential physical damage in the case of tidal turbines (Carstensen *et al*., 2006; Evans, 2008). On the hand, once wind farms are under production, it is possible they could have positive effects if they form safe havens for fish (Evans, 2008).

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