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FOREWORD

Climate change and marine mammals

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Climate change is now widely recognized as a global issue (IPCC, 2007). Whereas the Earth's climate has exhibited broad extremes over geological time there is a consensus that the rate of global warming is unprecedented in both terrestrial and marine environments. Ocean climate is largely defined by its temperature, salinity, ocean circulation and the exchange of heat, water and gases (including CO_2) with the atmosphere. The functioning of our marine ecosystems is highly dependent on changes to both ocean climate and acidification, whilst storms and waves, sea-level rise and coastal erosion pose clear threats to human life as well as to other creatures (MCCIP, 2010).

Marine air and sea temperatures have risen over the north-east Atlantic in the last 25 years, the largest increase in sea surface temperatures occurring in the southern North Sea and eastern English Channel, at a rate of between 0.6 and 0.8° C per decade (Rayner *et al.*, 2003; IPCC, 2007). Although inter-annual variability is high, the first decade of the 2000s has been the warmest on instrumental record (IPCC, 2007; Hughes *et al.*, 2010). The rate of change in ocean pH is thought to be faster than anything experienced in the last 55 million years, with a 30% decrease in pH, and a 16% decrease in carbonate ion concentrations since 1750 (Caldeira & Wickett, 2003; IPCC, 2007; Doney *et al.*, 2009). Although the Arctic is characterized by large temporal and spatial variations in climate, the past few decades have seen record minima in sea ice coverage during summer and increased melt from Greenland, which has exceeded the range of natural variability over the past thousand years (Morison *et al.*, 2000; ACIA, 2004; IPCC, 2007; Walsh, 2008). In the North Atlantic, unstable weather patterns leading to increased frequency of cyclones and other types of storm, appear to be influenced at least in part by what is referred to as the North Atlantic Oscillation (NAO), the index of which is a measure of the difference in mean atmospheric pressure between high pressure in the Azores (or Gibraltar) and low pressure in Iceland. The recent strong trend in the NAO (towards stormier conditions) is apparently unique in its history, but it is still under debate as to whether or not this is a response to greenhouse gas forcing (Osborn, 2004). More general changes in westerly winds in the North Atlantic region are implicated in changes in wave heights and storminess around Western Europe, and the behaviour of the NAO is not the only relevant factor. Another pattern of atmospheric pressure anomalies, the East Atlantic Pattern (EAP), appears to explain a large part of the inter-annual variability in winter wave climate in the region, where significant increases have taken place between the 1960s and early 1990s (Woolf *et al.*, 2002).

Climate changes have also been reported from the Mediterranean Sea, a semi-enclosed basin covering only 0.82% of the planet's ocean surface and characterized by a rather fast turnover time (Bianchi & Morri, 2000). Boero and colleagues (2008) reviewed water temperature and salinity levels over the last decades, reporting higher levels throughout the entire Mediterranean Sea attributable to climate changes. In response to this, sea level is expected to rise in the near future, with values from north-east Spain indicating an increase of 3.3 cm over a time-frame of 11 years (Salat & Pascual, 2002). The effects of climate change over the Mediterranean Sea have been the subject of several recent studies (Boero *et al.*, 2008; Gambaiani *et al.*, 2009; Lejeusne *et al.*, 2009), with predicted changes in prey availability and distribution over the water column and increases in the presence of alien (exotic) species, due to the 'tropicalization' of the entire area (Bianchi, 2007).

As an example, the potential effects of global climate change or ocean acidification on Mediterranean fin whales, reproductively isolated from their North Atlantic conspecifics and largely dependent for feeding on euphausiids such as *Meganyctyphanes norvegica* (Notarbartolo di Sciara *et al.*, 2003), as well as possibly susceptible to an increase in water temperature and salinity (Gambaiani *et al.*, 2009), may strongly influence the entire population, leaving no space to move to northern latitudes.

A number of reviews have been published recently of the possible effects of climate change upon marine mammals (IWC, 1997, 2009; Würsig *et al.*, 2002; Learmonth *et al.*, 2006; Huntington & Moore, 2008; Laidre *et al.*, 2008; MacLeod, 2009; Evans *et al.*, 2010). Marine mammals, as warm-blooded thermo-regulating vertebrates, might be expected to cope well with most environmental variation predicted from climate change. They employ complex behavioural adaptations 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, changes in the availability of their habitat (including food resources) may 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 or ringed seal, and its consequent effect upon Arctic 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 (Huntington & Moore, 2008; Laidre *et al.*, 2008; IWC, 2009; MacLeod, 2009). Other physical changes to the habitat include increased sea levels modifying shallow seas. This could affect the hydrodynamics and physiography of bays and lagoons used for breeding by coastal species such as the gray 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, the diets of all of which appear to depend upon shallow-water species (seagrasses in the case of sirenians—see Short & Neckles, 1999; and fish and invertebrates in the case of cetaceans—see Würsig *et al.*, 2002; Learmonth *et al.*, 2006). With rising sea levels, many of the current shallow areas (for example in the western Pacific) will be lost.

The theme of the European Cetacean Society's 23rd Annual Conference, held in Istanbul, Turkey, in March 2009, and hosted by the Turkish Marine Research Foundation, was 'Climate change and marine mammals', with two invited key-note presentations. Mads-Peter Heide-Jørgensen from the Greenland Institute of Natural Resources reviewed the results of recent research on impacts upon Arctic marine mammals, identifying the narwhal and polar bear as highly sensitive due to their narrow habitat selection, reliance on sea ice and specialized feeding, whilst the least sensitive were the ringed seal and bearded seal, primarily due to large circumpolar distributions, large population sizes, and flexible habitat requirements. The bowhead whale seems to be relatively plastic in its movement patterns (unlike the narwhal) and more flexible in its habitat utilization, apparently recently taking advantage of the receding sea ice in spring to utilize new habitats for feeding (switching between pelagic concentrations of copepods and benthic decapods). In this way, the species is able to withstand possible mismatches between primary and secondary production caused by changes in sea ice recession in the critical spring months (Heide-Jørgensen, 2009).

Less clear have been the possible effects on climate change on coastal dolphins. Randall S. Wells of the Mote Marine Laboratory in Florida highlighted the value of long-term research studies drawing upon the findings of more than thirty years' study of bottlenose dolphins in Sarasota Bay. At the extremes of the species' range, bottlenose dolphins have exhibited behavioural plasticity, through short- and long-term range shifts correlated with changes in water temperature. However, range shift options may be limited for resident communities located well within their range where adjacent waters are already occupied by other bottlenose dolphin communities. Those remaining in warming waters may experience changes in prey availability as well as increased exposure to biotoxins and environmental contaminants that could impact their survival and/or fecundity (Wells, 2009). The take-home messages from these two presentations were the enormous challenge posed by the need to understand likely effects of climate change, and the value of in-depth research and long-term monitoring.

Many of the contributions to the *Journal of the Marine Biological Association of the United Kingdom*'s fourth special issue on marine mammals (2010) provide pieces in the puzzle that will give us a better appreciation of how marine mammals may respond to environmental change.

For many species and areas, knowledge of life history and habitat use is currently at a fairly basic level and such baseline information is needed before effects of climate change or other potential threats can be evaluated.

One recurring theme is the need to consider individual variability within populations, and the value of photo-identification to collect such data. Espécie and colleagues (2010) report that individual Guiana dolphins, *Sotalia guianensis* show different degrees of residency in a bay in Brazil, and they suggest that the presence of some individuals is related to local resource availability. Oshima *et al.* (2010) found that home ranges of the same species in the Cananéia Estuary, Brazil, also showed great individual variability. Boye *et al.* (2010) showed that although the same humpback whales use the Godthaabsfjord system, West Greenland, as a foraging area year after year, individuals did not remain in the fjord the entire season and the time spent in the fjord was highly variable amongst individuals.

Behavioural plasticity is one feature that could assist marine mammals to respond quickly to climate change. Humpback whales, *Megaptera novaeangliae* are well known for their lengthy song bouts uttered by males on the calving grounds. These songs are confined to a short period of time, yet change within a season but vary little between years. Wright & Walsh (2010) offer an explanation for this in the finding that there is a seasonal process of neurological development and atrophy similar to that found in other animals.

Range shifts in response to climate change have been demonstrated for a variety of fish species. Studies of trends in the diet of cetaceans can therefore yield insight as to possible effects. A study by Jansen *et al.* (2010) of the stomach contents of white-beaked dolphins, *Lagenorhynchus albirostris* collected from the Dutch coast over a period of 45 years interestingly indicated little change in species composition with gadoids dominating, particularly whiting *Merlangius marlangus* and cod *Gadus morhua*. In warmer waters off the coast of Brazil, a study by Melo *et al.* (2010) of the diet of six delphinid species found that cephalopods were important, particularly the squid *Loligo plei*, whilst overall species composition suggested a preference for coastal and demersal prey. Although particular prey species and/or size-classes may be more important than others in the diet of cetaceans, most nevertheless appear to be to some extent opportunistic, taking a wide variety of prey. The same appears to be true of a number of pinniped species. Scat and fatty acid analysis by Kavanagh *et al.* (2010) of harbour seals *Phoca vitulina* from the Atlantic coast of Ireland highlighted their catholic diets, with 18 prey species identified, although sole *Solea solea*, sandeels *Ammodytes* spp. and *Trisopterus* species did predominate.

Species' food preferences and avoidance of competition are likely to be important factors in habitat partitioning. In

Cardigan Bay, Wales, Simon *et al.* (2010) demonstrated using acoustic monitoring that porpoises rarely occurred in the vicinity of bottlenose dolphins, despite their overlapping diets, probably because bottlenose dolphins pose a direct threat to them. In those areas, both species are occupying relatively shallow coastal waters, and their interactions could be affected by environmental change. One species that is particularly a habitat specialist, associated with the coastal strip, is the Guiana dolphin. Wedekin *et al.* (2010) studied its habitat preferences in southern Brazil, and found that, over a five-year period from 2001–2005, the species favoured certain areas but shifted its spatial use apparently in response to changes in abundance of certain prey, particularly the collapse of one local fish stock. The north-eastern coast of Venezuela hosts a high diversity of marine megafauna, particularly related to the high productivity arising from coastal upwellings there. Oviedo *et al.* (2010) found that areas of highest densities of common dolphins, *Delphinus* spp., coincided with the centre of sardine fisheries and the most active upwellings on the north-eastern coast.

Evaluation of potential effects of climate change on species distribution may be assisted by predictive models relating sightings rates to environmental variables. This presents several challenges, from accounting for variation in detection rate (e.g. the effect of visibility or sea state) to obtaining relevant environmental data at appropriate spatial and temporal scales and resolutions. Where empirical relationships are discovered it is important to identify the underlying mechanisms and the functional significance, determination of which will help avoid falling into the trap of ascribing biological significance to coincidental relationships. Pierce *et al.* (2010) found that bottlenose dolphin sightings from the coast tended to be associated with more productive areas (areas with higher chlorophyll-*a* concentrations) in Galicia (north-eastern Spain) and, while the obvious interpretation is that this is related to abundance of food, this remains to be demonstrated.

Estimates of absolute abundance remain fundamental to understanding of conservation status, especially in threatened populations and/or rare species such franciscana dolphins in southern coastal Brazil (see Danilewicz *et al.*, 2010). Nevertheless, an ongoing issue with assessing the conservation status of marine mammals is the difficulty and expense of conducting large-scale surveys on a regular basis. A possible way of extracting useful information on trends from more limited data is described by Hall *et al.* (2010), who show that abundance–occupancy (or density–occupancy) relationships can be applied in some small cetaceans. Brito & Vieira (2010) point to the potential of historical accounts to provide new data on cetacean occurrence and distribution in poorly studied regions. Encounter rates from boat-based surveys, even when absolute abundance cannot be estimated, can be used to expand and clarify information on the distribution of cetacean species, as reported by Boisseau *et al.* (2010) for the Mediterranean. Weir *et al.* (2010) used dedicated survey sightings and reliable anecdotal records to document killer whale occurrence in Angolan and Gulf of Guinea waters off tropical West Africa. And De Boer (2010) used boat-based surveys to record cetacean distribution and relative abundance in offshore Gabonese waters.

Methodological issues remain to be solved for estimation of both absolute and relative abundance. Thus in order for long-term trends in relative abundance of harbour seals to be determined from counts at haul-outs, it must be assumed that the mean number of seals at a particular site does not vary during the survey period, and that the start and duration of the survey window does not vary with location or between years. Cunningham *et al.* (2010) used a combination of repeat land-based and aerial surveys to test the assumption for constancy of counts during the survey period.

Life history information (e.g. age distribution, age at maturity, etc) can be essential to help interpret other data on population status as well as providing direct information on population birth and mortality rates. Botta and colleagues (2010) found that growth curves in franciscana dolphins, *Pontoporia blainvillei* were very similar in two areas, southern Brazil and northern Argentina. Perhaps less obviously, in socially living animals such as many cetaceans, a good understanding of social interactions can help to inform our view of population status. In bottlenose dolphins, *Tursiops truncatus*, from Panama City, male associations are stronger than inter-sexual associations or those between females only (Bouveroux & Mallefet, 2010). Results from a study of behavioural strategies on humpback whales in a coastal region of Brazil by Lunardi *et al.* (2010) indicate a clear-cut relationship between competitive groups and the occurrence of aggressive behaviours, and identified a preferential association of males with females of high reproductive potential for the following year (i.e. females without a calf).

The 'marine mammal' special issues aim to cover the full range of current research on marine mammals and it is appropriate therefore that this fourth special issue also contains papers describing new methodologies and findings relevant to the ethical conduct of research. Sánchez-Garcia *et al.* (2010) show that image processing methodology can be applied to achieve automated detection, extraction and characterization of marine mammal tonal calls from underwater sound recordings. Cantor *et al.* (2010) report that biopsy sampling of humpback whales for molecular genetic studies, can generally be achieved with no detectable response from the animals. Where a response was seen, it was most often a low-level category of reaction. The authors also note that the use of larger boats resulted in less intense responses.

In recent times, the credibility or otherwise of the IPCC and its predictions has been the subject of debate in the popular press, not all well-informed. However, the existence or otherwise of directional climate change should not distract us from the very real and potentially detrimental effects of current climatic variation on a number of marine mammal species. The need for action to conserve vulnerable species and populations remains pressing. Climate change is of course just one of the challenges facing marine mammal populations, emphasizing the importance of a good understanding of their biology and ecology as an aid to understanding how such potential threats may impact on populations. We are still far from understanding synergistic or cumulative effects from a variety of human activities, and it is only by studying each of these in greater detail, and in a variety of species and contexts, that we are likely to be able to better address the role played by climate change.

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