IMPACTS OF CLIMATE CHANGE ON MARINE MAMMALS

Ian Boyd and Nora Hanson
Sea Mammal Research Unit (SMRU) Gatty Marine Laboratory, University of St Andrews

Executive Summary

There is little useful information available to provide a formal assessment of the effects that climate change scenarios are likely to have on marine mammals. Most assessments suggest that the effects will be greatest amongst species that are most heavily dependent upon sea ice for their ecology. There appear to be no special circumstances to suggest that marine mammals around the UK are likely to be affected severely by climate change, although some migratory species that pass through UK waters to and from Arctic breeding grounds may be affected. However, since we do not have sufficient information about the populations of these species, any effects of climate change will probably pass unnoticed. This reflects a general problem with our power to detect even large changes in the population status of most of the marine mammals around the UK.

Based upon an analysis of individual species vulnerabilities, it should be possible to develop an approach to assessing the risks to different species. To date this has not been done but there may be a need to undertake this analysis soon as an aid to policy development and management because of the need to avoid synergistic effects between climate change and anthropogenic stresses to marine mammal populations.

Level of Confidence

Overall, there is a **very low** level of confidence in the assessment of climate change on marine mammals. Much more could be done to improve the current level of confidence but there will always be an upper limit to our ability to link changes in marine mammal population, when they are detectable, to the physical or biological drivers associated with climate change. This ability will vary greatly between species. For seals, there is a comparatively high level of knowledge and flow of information (even compared with most other components of the marine ecosystem) but for many cetaceans there will never be sufficient knowledge at current levels of research investment to be able to infer with any reasonable level of confidence that population changes are the result of climate change.

Key sources of Information

See supporting evidence

Supporting Evidence

The effects of climate change on marine mammals will be caused by changes in the interactions between the physiological state of these animals and the physical changes in their environment caused by climate change. In this analysis, climate change is defined as a long-term (millennial) trend in the physical climate. This distinguishes it from short-term, regional fluctuations in the physical climate (e.g. Cavalieri *et al.*, 2003; Sun *et al*., 2004; Grebmeier *et al*., 2006). Since marine mammals are warm-blooded vertebrates with extreme control of their physiology and complex behavioural repertoires that adapt rapidly to changes in the conditions of the external environment, in general, we would expect the changes in the physical environment at the scales envisaged under climate change scenarios to be well within the homeostatic capacity of marine mammals. Equally, we should not imagine that any effects of climate change on marine mammals should necessarily be negative.

Marine mammals normally experience a level of variance in their environment that is very large compared with most variance predicted due to climate change. Examples include the temperature gradients that many marine mammals experience while diving through the water column and the extreme patchiness of the prey resources for marine mammals. The morphologies, physiologies, behaviours and life histories of marine mammals have evolved to cope with this high level of variance. However, it is generally accepted that climate change could result in non-linear processes of change in some of the physical and biological features of the environment that are important to some marine mammals species (Lusseau *et al.,* 2004). Although speculative, obvious changes such as the extent of Arctic and Antarctic season ice cover could affect the presence of essential physical habitat for marine mammals, and there may be other changes in the structure of marine mammal habitats that are less obvious and difficult to both identify and quantify. Through changes in the trophic structure of the oceans in icebound regions, the ecology of which is very reliant on sea ice, the trophic pyramid that supports these top predators could be altered substantially (Laidre and Heide-Jorgensen 2005).

A common approach to the assessment of the effects of climate change is to divide these into *direct* and *indirect* effects (Robinson *et al*., 2005). In this case, *direct* effects are those associated with changes in the physical environment, such as those that affect the availability of suitable habitat. *Indirect* effects are those that operate through the agency of food availability because of changes in ecology, susceptibility to disease, changed exposure to pollution or changes in competitive interactions. This division has little utility in terms of rationalising the effects of climate change because, in simple terms, the effects will operate ultimately through the availability of suitable habitat. Assessing the effects of climate change rests upon an assessment of whether there is a functional relationship between the availability of suitable habitat and climate, and the form of these functional relationships, which will differ between species, has not been determined.

The expansion and contraction of suitable habitat can be affected by a broad range of factors and some of these can operate on their own but others are often closely related and synergistic, such as the combined effect of retraction of sea ice upon the availability of breeding habitat for seals and also for the food chains that support these predators.

Evidence for the effects of climate change on marine mammals

There is no strong evidence that current climate change scenarios are affecting marine mammals although there are studies that suggest some typical effects of climate change could affect marine mammal distribution and abundance. There is an increasing body of literature that links apparent variability in marine mammal abundance, productivity or behaviour with climate change processes (Walther *et al*., 2002; Lusseau *et al.,* 2004; Forcada *et al*., 2005; Leaper *et al*., 2005; McMahon and Burton, 2005). However, with the probable exception of those documenting the changes occurring to the extent of breeding habitat for ringed seals within some section of the Arctic, and the consequences of this also for polar bears, (Derocher *et al.,* 2004; Ferguson *et al.,* 2005), most of these studies simply reflect a trend towards the interpretation of responses of marine mammals to large-scale regional variability in the physical environment, as has already been well documented in the Pacific for ENSO (Trillmich *et al*., 1991), in terms of climate trends. Long-term trends in the underlying regional ecosystem structure (e.g. Atkinson *et al*., 2004; Trites *et al*., 2006) are sometimes extrapolated as evidence of climate change (Walther *et al*., 2002). In few, if any, of these cases is there strong evidence that the physical environmental variability being observed is derived from irreversible trends in climate. Some of the current literature confounds understanding of the responses of marine mammals to regional variability with that of climate change, albeit that an understanding of one may be useful in the interpretation and prediction of the effects of the other.

Based upon records of species from strandings, MacLeod *et al.,* (2005) have suggested that the species diversity of cetaceans around the United Kingdom has increased recently and that this may be evidence of range expansion in some species. However, the sample sizes involved are small and there are difficulties in these types of studies accounting for observer effort. This is a common story for marine mammals, and many other marine predators including seabirds (Robinson *et al.,* 2005) in that there is a great deal of theory about what the effects of climate change might be but little convincing evidence that backs up these suggestions. Even process studies (e.g. Forcada *et al.,* 2005) when considered in detail make a tenuous linkage between the physical variables and the biological response of the marine mammals.

Sea level rise may affect current seal haul-out sites but we suspect that this will happen at a rate that would not prevent an adaptive shift in distribution to new haul-out sites. Some critical habitat, such as the Monach Isles might

disappear but other habitat would be created, and it is hard to say what balance there would be between gain and loss.

Is climate change research on marine mammals scientific?

Although it is beyond dispute that marine mammals respond to the physical effects upon habitat suitability, it is usually not clear what the relationship between a particular effect and the response from the marine mammal will be. Where data from time-series are analysed, as in the case of Forcada *et al.,* (2005), they are used to test *post-hoc* for relationships between climate and biological variables. There is a tendency in these circumstances to test for all possible relationships using a range of physical and biological variables. Such *post-hoc* testing is fraught with pitfalls because invariably the final apparently statistically significant relationships are not down-weighted in their significance by all the other non-significant relationships that were investigated alongside those that proved to be statistically significant. Of course, there may be *a priori* reasons for accepting that a particular relationship is true, but the approach to examining time-series rarely provides an analysis of the relationships that were not statistically significant or the *a priori* reasons there might be for rejection of these. Consequently, current suggestions from the literature about the potential effects of climate change may be exaggerated because of the strong possibility of the presence of statistical error in the assessment process. Moreover, the great majority of examples, it will be almost impossible to clearly demonstrate effects of climate change, as has been the case with partitioning the variance between a range of causes of the decline of the Steller sea lion (*Eumetopias jubatus*) (Trites *et al*., 2006).

Identifying situations in which climate change is likely to have a negative effect on marine mammals – future work

To date, little has been done to build predictive frameworks for assessing the effects of climate change on marine mammals. There have been broad assessments (Würsig *et al.,* 2002; Robinson *et al*., 2005) and focussed ecological studies but these are a fragile foundation for guiding policy and management, and for identifying populations that are at greatest risk. The resilience of marine mammals to climate change will simply reflect resilience to any other change in habitat quality. The resilience of marine mammal populations will depend upon the extent of suitable habitat, the degree to which populations currently fill that habitat, the dispersal capacity of the species and the structure of the current population, including its capacity for increase and demographics. Clearly, populations that are already in a depleted state, or that are dependent upon habitat that is diminishing for reasons other than climate change will be more vulnerable to the effects of climate change (Green and Pershing 2004; Heide-Jorgensen and Laidre 2004). There are also some, as yet unconvincing, suggestions that habitat degradation may occur through effects of climate upon pollutant burdens (MacDonald *et al.,* 2005).

The general demographic characteristics of marine mammal populations are relatively well known so there are simple ways of assessing the risk to populations under different scenarios of demographic stochasticity, population size and isolation. An analysis of this type could only provide a very broad guide to the types of effects that could be expected but, although no such analysis has been carried out to date, this should be seen as a first step in the risk assessment process.

The metapopulation structure will affect resilience to climate change and will be reflected in the dispersal capacity of the population. Again, this type of effect could be developed within an analysis of the sensitivity of marine mammal populations under different metapopulation structures. A feature of climate change is that it is likely to have global as well as local effects and the sensitivity to the relative contribution from these would be an important feature of such an analysis.

Please acknowledge this document as: Boyd, I. and Hanson, N. (2006). Impacts of Climate Change on Marine Mammals *in* Marine Climate Change Impacts Annual Report Card 2006 (Eds. Buckley, P.J, Dye, S.R. and Baxter, J.M), Online Summary Reports, MCCIP, Lowestoft, www.mccip.org.uk

References

Atkinson, A., Siegel, V., Pakhamov, E. and Rothery, P. (2004), Long-term decline in krill stocks and increase in salps within the Southern Ocean, *Nature* **432**; 100-103.

Cavalieri, D. J., Parkinson, C.L. and Vinnikov, K.Y. (2003). 30-Year satellite record reveals contrasting Arctic and Antarctic decadal sea ice variability, *Geophysical Research Letters*, **30**(18), 1970, doi:10.1029/2003GL018031.

Derocher, E., Lunn, N. and Stirling, I. (2004). Polar bears in a warming climate, *Integrative and Comparative Biology* **44**; 163-176.

Ferguson, S., Stirling, I. and McLoughlin, P. (2005). Climate change and ringed seal (*Phoca hispida*) recruitment in western Hudson Bay, *Marine Mammal Science* **21**(1); 121-135.

Forcada, J., Trathan, P., Reid, K. and Murray, E. (2005). The effects of global climate variability in pup production of Antarctic fur seals, *Ecology* **86**(9); 2408-2417.

Grebmeier, J., Overland, J., Moore, S., Farley, E., Carmack, E., Cooper, L, Frey, K., Helle, J., McLaughlin, F. and McNutt, S. (2006). A major ecosystem shift in the northern Bering Sea, *Science* **311**; 1461-1464.

Green, C. and Pershing, A. (2004). Climate and the conservation biology of North Atlantic right whales: the right whale at the wrong time? *Frontiers in Ecology and the Environment* **2**(1); 29-34.

Heide-Jorgensen, M.P. and Lairde, K.L. (2004). Declining extent of open water refugia for top predators in Baffin Bay and adjacent waters, *Ambio* **33**(8):487-94.

Hunt, G., Stabeno, P., Walters, G., Sinclair, E., Brodeur, R., Napp, J. and Bond, N. (2002). Climate change and control of southeastern Bering Sea pelagic ecosystem, *Deep Sea Research II* **49**; 5821-5853.

Laidre, K. and Heide-Jorgensen, M. (2005), Artic sea ice trends and narwhal vulnerability, *Biological Conservation* **121**; 509-517

Leaper, R., Cooke, J., Trathan, P., Reid, K., Rowantree, V. and Payne, R. (2005) Global climate drives southern right whale (*Eubaena australis*) population dynamics, *Biology Letters* **2**(2) doi:10.1098/rsbl.2005.0431.

Learmonth J.A., Macleod C.D., Santos M.B., Pierce G.J., Crick, H.Q.P., Robinson, R.A. (2006) Potential effects of climate change on marine mammals *Oceanography and Marine Biology* 44, 431-464

Lusseau, Williams, R., Wilson, B., Grellier, K., Barton, T.R., Hammond, P.S., Paul., Thompson, M. (2004). Parallel influence of climate on the behaviour

of Pacific killer whales and Atlantic bottlenose dolphins. *Ecology Letters* **7**; 1068-1076.

MacDonald, R., Harner, T. and Fyfe, J. (2005). Recent climate change in the Artic and its impact on contaminant pathways and interpretation of temporal trend data, *Science of the Total Environment* **342**; 5-86.

MacLeod, C., Bannon, S., Pierce, G., Schweder, C., Learmonth, J., Herman, J. and Reid, R. (2005). Climate change and the cetacean community of north-west Scotland, *Biological Conservation* **124**; 477-483.

McMahon, C. and Burton, C. (2005). Climate change and seal survival: evidence for environmentally mediated changes in elephant seal *Mirounga leonina* pup survival, *Proceedings of the Royal Society B* **272**; 923-928.

Robinson, R., Learmouth, J., Hutson, A., Macleod, C., Sparks, T., Leech, D., Pierce, G., Rehfisch, M. and Crick, H. (2005), Climate change and migratory species. *BTO Research Report 414*. Available at http://www.defra.gov.uk/wildlife-countryside/resprog/findings/climatechange-migratory/climatechange-migratory.pdf.

Sun, L., Liu, X., Yin, X., Zhu, R., Xie, Z. and Wang, Y. (2004). A 1,500-year record of Antarctic seal populations in response to climate change *Polar Biology* **27**; 495-501.

Trillmich, F., K.A. Ono, D.P. Costa, R.L DeLong, S.D. Feldkamp, J.M. Francis, R.L. Gentry, C.B. Heath, B.J. LeBoeuf, P. Majluf, and A.E. York. (1991). The effects of El Niño on pinniped populations in the eastern Pacific. *In*: Fritz Trillmich and Kathryn A. Ono (editors), *Pinnipeds and El Niño: Responses to environmental stress*, p. 247-270. Springer-Verlag, Berlin, Germany. 293p.

Trites, A., Miller, A., Maschner, H., Alexander, M., Bograd, S., Calder, J., Capotondi, A., Coyle, K., Di Lorenzo, E., Finney, B., Gregr, E., Grosch, C., Hare, S., Hunt, G., Jahncke, J., Kachel, N., Kim, H., Ladd, C., Mantua, N., Marzban, C., Maslowski, W., Mendelssohn, R., Neilson, D., Okkonen, S., Overland, S., Reedy-Maschner, K., Royer, T., Schwing, F., Wang J. and Winship, A. (2006). Bottom up forcing and decline of Stellar Sea Lions in Alaska: assessing the ocean climate hypothesis, *Fisheries Oceanography* (In press).

Walther, G., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T., Fromentin, J., Hoegh-Guldberg, O. and Bairlein, F. (2002). Ecological responses to recent climate change. *Nature* **416**; 389-395

Würsig, B., Reeves, R.R. and Ortega-Ortiz, J.G. (2002). Global climate change and marine mammals. In: Evans, P.G.H. and Raga, J.A. [Eds] *Marine mammals – biology and conservation.* Kluwer Academic/Plenum Publishers, New York.