Report of the Workshop on Small Cetaceans and Climate Change

The workshop was held at the Federal Ministry of Agriculture, Forestry, Environment and Water Management in Vienna, Austria from 28 November to 1 December 2010. The list of participants is given at Annex A.

1. INTRODUCTORY ITEMS

1.1 Welcome and Introduction

Andrea Nouak (IWC Commissioner for Austria) welcomed participants to Austria and Mark Simmonds (Workshop Convenor) thanked Dr Nouak and the Government of Austria for the invitation to meet in Vienna and for hosting the meeting. He also thanked the Governments of the US, Australia and Germany as well as WWF and WDCS for sponsoring the workshop and making it possible. He expressed gratitude to the participants for attending, especially those that had come long distances, and the IWC staff especially Julie, Sandra, Greg and Simon for their support for this initiative. He noted that the background to the work of the IWC on environmental threats was detailed in the report of the second IWC workshop on climate change which had been held in Siena in 2009 (IWC 2010).

Simmonds commented that whilst attention had largely been focused on the effects of climate change on land, the ocean and the atmosphere were inexorably linked and it was the interactions between the two that regulated the Earth's climate. Human-induced changes to the atmosphere were now leading to changes in the oceans and these same oceans are in fact the Earth's most significant global heat buffer and also distribute heat around the planet, pumping warm water and air toward the poles and cold water and air back to the tropics. Major changes in ocean currents could lead to major shifts in weather patterns and regional climate, with impacts on all life forms. The oceans also absorb significant quantities of carbon dioxide and, bearing all these things in mind, future discussions concerning our need to mitigate and adapt to continuing global climate change should, therefore, include the consideration of ocean ecosystems (Herr and Galland 2009). Cetaceans were potentially important sentinel species for climate change (Moore 2008) and have been the focus of some recent increasing international interest and assessments (e.g. Whitehead and Worm, 2008; Alter et al., 2010; Simmonds and Elliot, 2010).

The first IWC workshop on climate change was held in Hawaii in March 1996. It was felt at that time that health problems associated with thermal change were unlikely for cetaceans and, instead, that workshop focused on the potential impacts of climate change on prey and the interplay between global climatic change, chemical pollution and pathogens. Broad areas of concern were identified, including the potential that some recent marine mammal epizootics had been exacerbated by climate change. However, in its conclusions, the first IWC workshop 'recognised that given the uncertainties in modelling climate change at a suitable scale and thus modelling effects on biological processes at present it is not possible to model in a predictive manner the effects of climate change on cetacean populations'. A summary of the second IWC climate change workshop (the 2009 Siena workshop) is given below under item 3.1.

After the Siena workshop reported back, the IWC passed a resolution on climate change by consensus at its 2009 annual meeting. Apart from calling for climate change to be addressed and endorsing the findings of the Scientific Committee and the workshop, this resolution also requested 'Contracting Governments to incorporate climate change considerations into existing conservation and management plans'[1].

This 'Vienna Workshop' thus follows on from the 2009 Siena workshop. Its focus, scope and a list of proposed invited participants had been identified by a steering committee and endorsed and elaborated at the 2010 IWC scientific committee meeting, which concluded that the workshop would include some 10-12 participants; meet for 3 days; its report would be provided to the IWC Scientific Committee, Conservation Committee and Commission meeting; and all species of small cetaceans would be considered by the workshop (i.e. including river dolphins and small whales[2]).

Simmonds also reported that at the 2010 Scientific Committee meeting, the progress of work derived from the second climate change workshop had been noted, including planning discussions for a comparison of physical indicators of climate change and available data on population dynamics and behavioural ecology of the Bering-Chukchi-Beaufort and Hudson Bay-Davis Strait populations of bowhead whales. A list of available physical and biological data sets was being assembled for both populations, after which a formal outline and

[1] The full text of the resolution is available on the IWC website at: http://www.iwcoffice.org/_documents/commission/IWC61docs/61-16.pdf

[2] e.g. beaked whales

timeline for completion of the proposed study would be developed. The 2009 Siena workshop had also recommended that studies on southern right whales with distributions off South Georgia, the Antarctic Peninsula and the Eastern Antarctic be developed, with a focus on determining measurable responses to climate change. Work was ongoing including modelling by Justin Cooke.

1.2 Appointment of Officers
Arne Bjørge and Mark Simmonds were elected to co-chair the meeting. Heidrun Frisch, Simon Brockington and Mark Simmonds acted as rapporteurs.

1.3 Adoption of the Agenda
The workshop reviewed its agenda and made some small modifications. The revised agenda is given in Annex B. Papers submitted to the workshop are listed in Annex C and other references are given in full in the reference list (section 7).

2. WORKSHOP OBJECTIVES

2.1 Summary of Objectives
The workshop aimed to identify species, areas and research situations that could be informative for improving the understanding of how populations are likely to respond to climate change, with a specific focus on two major aspects: (1) Restricted habitats, including estuaries, rivers and shallow waters; (2) range changes, i.e. evidence of changes in distributions, reasons and consequences; and a third minor aspect: (3) the Arctic region.

Further details are in the report of the 2010 Scientific Committee (International Whaling Commission, *in press*).

3. OVERVIEW OF EXISTING RESEARCH AND HYPOTHESES

3.1 Report of IWC Second Workshop on Climate Change (CC2)
The 2009 Siena workshop (CC2) took as its primary goal the determination of how climate change may affect cetaceans; how to best determine these effects; and how to improve conservation under the climate change scenarios now described in the fourth (and far more comprehensive) report of the IPCC (IPCC, 2007). The workshop examined case studies from both large and small cetaceans and covered a number of topics including the evaluation of analytical and modelling approaches to investigating the linkages between whales and their environment, with an emphasis on climate change. Like its predecessor, this IWC workshop made a number of research recommendations, all of which were endorsed by the subsequent meetings of the full IWC Scientific Committee and the Commission in June 2009. Several of the key research recommendations were summarised by Simmonds (see box).

Key Recommendations of the Second IWC Workshop on Cetaceans and Climate Change (IWC, 2010)

- Give priority to developing models that can integrate the demographic and spatial consequences of climate change
- Explore the value of developing ecosystem models that begin with baleen whale dynamics
- Evaluate whether the present scenarios examined in the IWC's management procedures adequately addressed climate impacts or need further modification
- Try to find datasets that allow further correlative studies to be undertaken that will improve the conceptual understanding of population processes, and hence enable the development of a set of testable hypotheses
- Carefully review the predictions and levels of uncertainty of the IPCC modelling exercises in order to determine those most appropriate for incorporation into modelling exercises with respect to cetaceans, taking into account temporal and spatial scales and separating out factors such as mean overall SST warming from the changes in the positions of fronts and water masses
- Increase telemetry studies and explore the data for correlation between movement patterns and environmental variables – the results of these analyses may be used as basis for developing hypotheses regarding the mechanisms which determine movement
- Give emphasis to studies which allow comparison between contrasting regions where data on a wide range of ecosystem components are available.

Please refer to the full report of the Siena workshop (IWC 2010) for all recommendations and further details. The Siena workshop also made two recommendations that were of immediate relevance to the IWC Governments and relevant organizations:

1) that potential effects of climate change on cetaceans are taken seriously and included in relevant conservation management initiatives, including implementation of emission control; and
2) that funding be provided to ensure the continuation of long-term datasets given their great value.

Climate change impacts can be referred to as primary (meaning that there is a direct physical impact); secondary (referring to an indirect impact, especially one mediated via prey changes) and tertiary (Alter *et al.*, 2010 and Gambaiani *et al*. 2009). This last category refers to the reactions by the human population to changes in climate which then impact cetaceans and the IWC Scientific Committee also requested that the Commission urged policy makers, regulators and others involved in cetacean management to consider tertiary effects of climate change via appropriate risk assessment approaches; recommending that management plans are devised to address these impacts in addition to primary and secondary impacts. A further IWC workshop to elaborate the significance of climate change for small cetaceans was proposed; a recommendation that led to the 2010 Vienna workshop.

3.2 Consideration of Hypotheses from CC2

The Small Cetacean Working Group at CC2 developed a set of hypotheses on the relationship between climate-induced stressors and their impact on small cetaceans. Testing these would require broad, multi-disciplinary approaches. They were:

HYPOTHESES RELATED TO TEMPERATURE
T1: Small cetacean species will redistribute to avoid thermal stress where possible;
T2: Modification of ecosystem structure and productivity will lead to changes in cetacean distribution to meet trophic demands;
T3: Species in restricted habitat with little or no capacity to redistribute will be exposed to thermal, nutritional and health related stress.

HYPOTHESES RELATED TO HYDROLOGY
FW1: Changes in hydrological regime will entail changes in habitat use for obligate freshwater and estuarine species and populations.

HYPOTHESES RELATED TO SEA LEVEL RISE AND GEOMORPHOLOGIC ALTERATIONS
SL1: Changes in salinity and sedimentation rates will entail habitat alterations for riverine and estuarine species;
SL2: Sea level rise will physically reduce habitat for obligate freshwater species;
SL3: Loss of supporting habitat for coastal/estuarine species, including small cetaceans and their prey (sheltering areas, nurseries for prey species, etc.).

3.3 Consideration of Other Relevant Information, Including Recently Published Reviews

Simmonds presented Alter *et al.* (2010) on forecasting the consequences of climate-driven shifts in human behaviour on cetaceans. This looked at tertiary effects of climate change, i.e. impacts on cetaceans from changes in human behaviour, including a tentative analysis and conclusions. An example of such a tertiary effect was the predicted increase in shipping traffic in Arctic waters as they became more easily navigable, resulting in more frequent incidences of ship strikes, besides other related threats and disturbances. Overall, the authors suggested that the most vulnerable species included tropical coastal and riverine species, such as the Irrawaddy dolphin, Indo-Pacific humpback dolphin and finless porpoise.

Simmonds further pointed to the report of the 2004 IWC Workshop on Habitat Degradation (IWC 2006). It included conceptual approaches which might help inform the debate on dealing with the problem of differentiating between the effects of climate change and those of other factors impacting on small cetaceans. Attention was drawn to Figure 2 of the report (reproduced below), which illustrates the gradient from pristine to degraded habitat and indicates likely associated population states along this spectrum, where population resilience can or cannot compensate and populations therefore may be driven to extirpation unless habitat degradation is reversed. The 2004 workshop had recommended a framework for modelling the links between environmental stressors and population effects. The workshop had recommended developing further methodological approaches to distinguish the relative effects of different stressors via population and spatial modelling approaches. This, however, had never been taken forward. Other recommendations concerned long-term studies, the development of new indices for the response to stressors as well as environmental indices, tagging studies, standardization of necropsy techniques and interdisciplinary research.

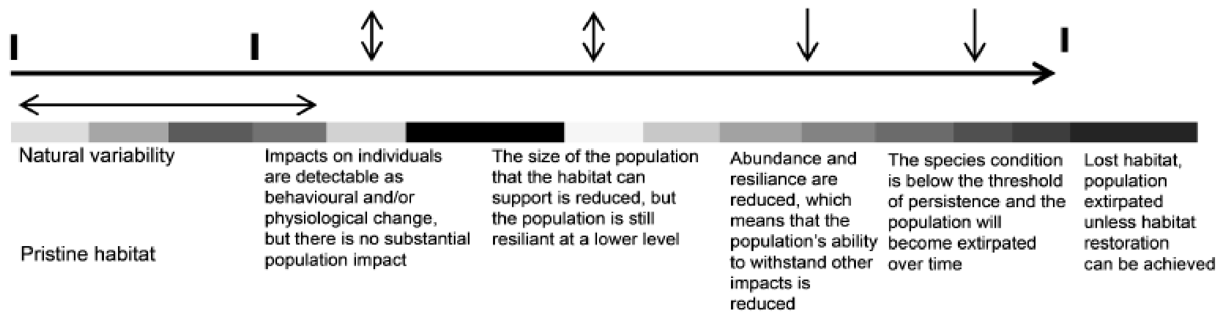


Fig. 2. The shading indicates the gradient from pristine to degraded habitat, vertical two-way arrows indicate states of habitat degradation where population resilience can compensate, downwards arrows indicate habitat states where population resilience cannot compensate and populations therefore are driven to extirpation unless habitat degradation is reversed.

3.4 Key Presentations

3.4.1 The Arctic Sea

O'Corry-Crowe gave an overview of recent climate related studies in the Arctic. The Arctic was changing rapidly and several predictions had been made as to the likely effects of these physical changes on small cetaceans, including changes in behaviour, distributional shifts, changes in health and genetic effects. Concerns primarily centred on the two endemic small whale species that lived in association with Arctic sea ice much of the year, the beluga whale,(*Delphinapterus leucas*) and narwhal (*Monodon monoceros*).

Some of the most dramatic losses in sea ice had occurred in the Chukchi and Beaufort Seas in the western Arctic and it was here where much focus was being placed on the impacts of climate change on small cetaceans. Sightings of temperate species had increased dramatically in the past decade in this sector of the Arctic, including harbour porpoise (*Phocoena phocoena*) and killer whales (*Orcinus orca*). There had also been an increase in sightings of other cetacean species: fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*) and minke whales (*Balaenoptera acutorostrata*) whales. Finally, narwhal, an arctic species rarely observed in this region, had been seen with increasing frequency in recent years. Despite these apparent northward expansions, no distributional shifts had been detected as yet in beluga and bowhead populations.

A number of recent published reviews and primary literature on climate change and Arctic marine mammals (inc., Ecological Applications, Special Issue 2008 and references therein; Moore et al. 2008; Ferguson 2009; Kovacs et al. 2010) had predicted impacts on, and in some cases recorded initial evidence of, habitat loss, distributional shifts, increased predation and competition. Novel approaches including genetics and satellite tracking had also: (1) reconstructed contact routes between high arctic populations of beluga whales during past warm periods that identified likely future contact routes for arctic populations with implications for population dynamics, genetic exchange, and disease transmission (O'Corry-Crowe et al. 2010), and (2) used ancient DNA technology on faunal remains from Aleut midden sites to identify range expansions of Arctic marine mammal species, including beluga whales, south across the Bering Sea some 3,000yr BP during the Neoglacial (O'Corry-Crowe, in review).

More attention should now be given to predation, competition and food web effects. Initial evidence indicated that warming climate in the Arctic: (1) would have direct and indirect effects on all trophic levels and nutrient cycling in Arctic marine systems as well as on gross physical oceanography, (2) would likely increase species richness and competition initially, (3) might add an upper trophic level to Arctic marine food webs with cascading effects throughout, and (4) would increase the role of the ultimate apex predator/competitor, man, with ecosystem-wide consequences.

In discussion the workshop noted that changes in the extent of Arctic pack ice would have a major influence on the Arctic ecosystem, not just through lack of ice cover but also through increased wave fetch and storm events which might also result in behavioural responses such as animals needing to seek shelter more regularly. In considering competitive interactions in the Arctic the workshop discussed that evidence for competition between species was inferred rather than documented, as opposed to increasing evidence of predation (Fergusson 2009).

The increases in killer whales in Arctic waters represented the addition of a trophic level to the arctic ecosystem and the workshop discussed the potential for 'trophic cascades' such as had been observed in other ecosystems.

The workshop noted the general concern over the status of beluga and narwhal populations and considered how they might respond to climate related change. Narwhals were ice-obligate specialists and so there was likelihood that they might be affected most strongly by reduction in ice cover. However, they had endured warming periods in the past and might have adaptive strategies. Belugas were greater generalists and might be able to adapt more easily, but the speed of current climate change and associated increase in human activities remained a concern for both species. Other Arctic species, such as the ringed seal which required sea-ice covered with snow for successful breeding, might be similarly affected.

3.4.2 Barents Sea and adjacent areas

Bjørge presented a paper on white-beaked dolphin (*Lagenorhynchus albirostris*) densities and distributions in the Barents Sea and potential influences by the recent temperature increase (CC5). In 2002 a new Norwegian-Russian survey was initiated aimed at monitoring key parameters of the demersal and pelagic ecosystems of the Barents Sea. This survey was conducted annually in August-September, and the vessels carried marine mammal observers. The most frequently observed marine mammal species were minke, fin and humpback whales.

Since 2002, 645 sightings of 5735 white-beaked dolphins had been recorded. The data was gridded into 50 km grid cells along transects. A General Additive Model had been used to describe the white-beaked dolphin distribution as a function of the physical habitat and years as variables. The dolphins were associated with depth, temperature, temperature gradients and years, and the dolphins were primarily found south of or at the polar front (the highly productive mixing zone between warm Atlantic and cold Arctic water masses). Therefore, frontal and upwelling areas appear to be prime feeding habitats for white-beaked dolphins in the Barents Sea. The delphinids that are in this ecosystem already occur over a wide range of temperatures and their ranges may therefore not be directly limited by ocean temperature. Climate changes influencing the properties of oceanographic fronts and upwelling areas could potentially have a larger effect on distribution than the temperature itself.

There is an indication of increasing densities of white-beaked dolphins in the Barents Sea, possibly due to increased immigration from the south causing a northward distribution shift of the species. If this shift represent a compressions of the range, it may entail enhanced inter- and intraspecific competition in the Barents Sea.

The workshop considered the hypothesis given in MacLeod (2008) that white-beaked dolphins are primarily a shelf species, and that a reduction in range out of the North Sea represents a compression of habitat for this species. It is possible that the carrying capacity of a compressed range may be reached, and discussion centred on whether this has been observed as a reduction in condition or health indices for individuals. White-beaked dolphins do not typically occur as bycatch (unlike harbour porpoises), and capture is difficult. However standard biopsy sampling is achievable as they regularly approach vessels and blubber analysis may be able to provide information on condition.

3.4.3 Restricted Habitats

3.4.3.1 CLIMATE CHANGE AND RIVER DOLPHINS IN SOUTH AMERICA

Trujillo presented on the effects of anthropogenic stressors on two species: the Amazon river dolphin (*Inia geoffrensis*) and the tucuxi (*Sotalia fluviatilis*), inhabiting the Amazon and the Orinoco basins, a large area of more than 7 million of square kilometers. The main stressors for these species were (1) deliberate killing of *Inia geoffrensis* to be used as bait to attract a scavenger fish locally know as mota or piracatinga (*Calophysus macropterus*), with an estimate of about 1200 killed dolphins per year in the central Amazon in Brazil alone and deliberate killing also reported from other areas (Flores et al., 2008); (2) oil and mercury pollution; (3) deforestation and habitat degradation; (4) negative interactions with fisheries; (5) dam construction; (6) hydro-way construction; (7) boat traffic; and (8) bad tourism practices.

The effects of climate change on river dolphins are not very clear, but probably include impacts on the availability of habitats and prey distribution. The reduction of precipitation and the increasing of temperature seemed to affect shallow water areas such as ox-bow lakes and wetlands, which were very important for fish spawning. Changes in total precipitation, extreme rainfall events, and seasonality would affect the amount, timing, and variability of flow.

WWF (2008) has summarized the effect of climate change in the aquatic ecosystems in the Amazon in four main points:

(1) Warming water temperatures might reduce the distribution of many fish species in the Amazon, and also affect lateral and longitudinal migrations. High temperatures might also result in reduced water dissolved oxygen concentrations, which might have immediate adverse effects on eggs and larvae, which relied on dissolved oxygen for survival (Carpenter et al., 1992).

(2) Decreased precipitation during dry months would affect primarily shallow water ecosystems, and also impact negatively the flooded forest that are very important to produce allochthonous food for fish during the rainy season. In the same way changes in flood pulses might have negative consequences for fish migration and connectivity of aquatic ecosystems.

(3) Changes in nutrient input into streams and rivers because of altered forest productivity might greatly affect aquatic organisms. Forested streams are highly dependent upon inputs of terrestrial organic matter, especially leaf fall, because of their nutrient supply. Shifts in terrestrial vegetation and changes in leaf chemistry would impact stream biota and ecosystems. In fact, several climate modelling studies and field

experiments showed that about 50% of the rainfall in the Amazon region originated as water recycled in the forest.

(4) More variable climate and more extreme events would impact local fish populations by more often exposing them to extreme events potentially producing lethal conditions for short periods of time. Changes in seasonal fluctuations might change the migratory pattern and ecology of fish species and lead to changes in fish catches (Cetra and Petrere Jr, 2001). Direct effects of climate change on river dolphins included reduction of prey, isolation in shallow waters and mortality and limitation of movements and migrations.

Trujillo highlighted that data on abundance and habitat use in the Amazon River in Colombia had been gathered systematically over more than 20 years. A photo-ID catalogue of river dolphins (*Inia geoffrensis* and *Sotalia fluviatilis*) with data on habitat use, resident patterns and movements had been created and base lines of abundance in selected rivers in Venezuela, Colombia, Ecuador, Peru and Bolivia had been established with

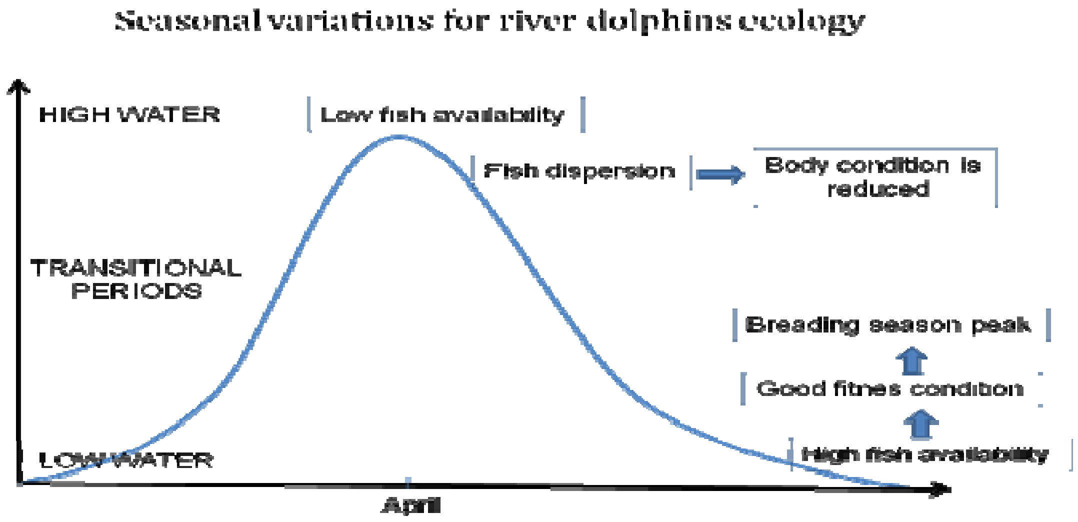


Figure 1. Seasonal variations in river dolphin ecology.

standardized methodologies. In addition, the research drew from other available datasets, such as hydrological information on temperature, river level and precipitation (available for the past 40 years) as well as fishery-related data on volume of captures, species composition, size and weight (available for the past 12 years).

Figure 1 indicates how climate change may affect patterns in habitat use, distribution and body condition of river dolphins.

3.4.3.2 CLIMATE CHANGE AND FRESHWATER DEPENDENT CETACEANS

Smith presented on the need for a comprehensive assessment on the implications of climate change for freshwater-dependent cetaceans (Smith *et al.* 2010). Freshwater-dependent cetaceans are amongst the most threatened species groups of large mammals. They can be classified in three categories: (1) those living exclusively in rivers and lakes, such as the boto, *Inia geoffrensis*, south Asian river dolphins, baiji, *Lipotes vexillifer*, and tucuxi, *Sotalia fluviatilis*; (2) those occurring primarily in marine waters but also some large rivers, which included the Irrawaddy dolphin, Guiana dolphin and the finless porpoise; and (3) those inhabiting nearshore marine areas with freshwater inputs, such as the humpback dolphin. The effects of climate change on these animals had not been rigorously assessed but could lead to population or even species extinctions, especially considering the cumulative impacts of climate change and other factors like bycatch, hunting and dam construction. If there was to be any chance of mitigating climate change-related threats to freshwater-dependent cetaceans, a much better understanding was needed of their habitat requirements and likely changes to the environments where they lived.

Natural variability in water discharge and sediment inputs determined the geomorphic and biological structure of rivers and gave them substantial resiliency to withstand or accommodate environmental disturbances, including those likely to be driven or exacerbated by climate change (Palmer *et al.* 2008). However, the natural resiliency of most of the world's major river systems had already been compromised by the construction of dams and by water withdrawals (Nilsson *et al.* 2005). Changes in the flow and sediment regimes of rivers had also altered salinity patterns, nutrient and sediment supplies, bottom topography, dissolved oxygen, and xenobiotic concentrations in open estuarine systems with deleterious consequences or biological productivity and diversity (Sklar and Browder 1998).

There might be few options available to prevent or mitigate the direct impacts of climate change on marine cetaceans. However, possibilities for freshwater-dependent species could include manipulation of upstream flows using existing water engineering structures to maintain suitable salinity gradients in estuaries and preserve essential habitat features, such as bars and mid-channel islands that induce counter-currents, in rivers. Possible approaches for mitigating the indirect effects of climate change included (1) reduction of cetacean bycatch in fisheries expected to expand with environmental changes associated with climate change; (2) management of climate-affected fisheries with due consideration for the prey of freshwater-dependent cetaceans; (3) elimination or reduction of contaminant inputs whose deleterious effects are expected to be magnified by changes in freshwater quality and supply predicted to accompany climate change; and (4) establishment of protected areas designed to ensure maximum resiliency to climate change-related impacts.

The way that freshwater-dependent cetaceans satisfy their life history needs (e.g., movement patterns, habitat use, foraging behaviour) could also give them particular value as indicators of certain ecological features of freshwater systems (e.g., concentrations of biological productivity) and for monitoring changes in these features that were expected to accompany climate change (Smith and Reeves, 2010). A better understanding of their potential role as 'ecosystem sentinels' could give additional weight to calls for their conservation.

O'Corry-Crowe stressed that the crucial role of top predators in the food web, whose removal would have strong cascading effects, could also serve for getting managers interested in their conservation, as this had a direct link to livelihoods and ecosystem services. Smith noted that to date there was very little information on the role of freshwater-dependent dolphins in their ecosystems.

The Workshop **recommended** that an assessment be conducted to provide resource managers, government officials and representatives of multi-lateral institutions with an in-depth understanding of the implications of climate change on freshwater-dependent cetaceans and to suggest a range of practical measures for mitigating climate-related threats. The Workshop also recognized that any meaningful assessment of the implications of climate change and any recommendations on management interventions for freshwater-dependent cetaceans needed to incorporate consideration of the impacts of water development.

3.4.3.3 CASE STUDIES OF MEDITERRANEAN, BLACK AND RED SEAS

Notarbartolo di Sciara provided a review of these areas. In 2007 the IPCC forecast a likely decrease in fresh water resources in Mediterranean-type ecosystems, reduction in rainfall, and multiple stressors to coral reefs and mangroves. Although a specific mention of change in the Mediterranean, Black and Red Seas' marine ecosystems relevant to cetacean conservation was not made, the general conclusion that can be drawn is that these ecosystems are likely to experience significant pressure from climate change. From the conclusions of the previous IWC climate change workshop, the hypotheses that more closely concern small cetaceans from the concerned regions are all temperature-related: T1 (species will re-distribute to avoid thermal stress); T2 (modification of ecosystem structure & productivity will lead to distributional changes); and T3 (species in restricted habitat with little or no capacity to redistribute will be exposed to thermal, nutritional and health related stress). All three regions are semi-enclosed within continents, which would prevent cetaceans from migrating northwards in response to warming.

The Mediterranean Sea

The Mediterranean Sea hosts native populations belonging to 7 species of Delphinids (*Globicephala melas, Orcinus orca, Grampus griseus, Tursiops truncatus, Stenella coeruleoalba, Delphinus delphis, Steno bredanensis),* one Ziphiid (*Ziphius cavirostris),* and one Phocoenid (*Phocoena phocoena relicta*) rare and limited to Northern Aegean waters. These populations are subject to a number of non-climate related pressure factors (bycatch, prey depletion, direct killings, chemical pollution, noise – from military and industry, ship strikes, habitat loss), some of which are causing them to be classified under various levels of threats, from Critically Endangered to Vulnerable.

Long-term changes in the basic patterns of circulation of the Mediterranean water masses have been detected in the past decades (e.g., Millot et al. 2002), which may have been caused by ongoing climate change. These are very likely to affect the patterns of primary productivity in the region, and ultimately cetacean ecology and conservation.

Ecological and geographical characteristics of the Mediterranean that are causing cetacean populations to be particularly vulnerable to change include: a) a very localised and reduced distribution of high levels of primary productivity in offshore waters; and b) the existence of very localised preferred habitat for some species (e.g., canyons for Cuvier's beaked whales). Evidence is available that critical habitat of some species (e.g., fin whales) has been fluctuating wildly in recent years. A hypothetical connection was proposed between climatic/meteorological events and a massive morbillivirus epizootic in 1990-92 (Aguilar and Raga 1993).

The Black Sea

The Black Sea hosts native populations belonging to two endemic subspecies of Delphinids (*Tursiops truncatus ponticus, Delphinus delphis ponticus),* and one Phocoenid (*Phocoena phocoena relicta*). Current non-climate related pressure factors include bycatch, chemical pollution, live captures for the captivity industry (limited to bottlenose dolphins) and habitat loss (direct killing had a major impact on all species in the past but ended in the 1980s). Both harbour porpoise and bottlenose dolphin (*Turiops truncatus ponticus*) are considered Endangered; the common dolphin is considered Vulnerable.

ACCOBAMS, the regional organisation concerned specifically with cetacean conservation in the above two regions, has recently (Nov. 2010) adopted a resolution (4.14) encouraging Parties to support the Agreement's Scientific Committee activities and to take necessary actions to reduce anthropogenic contributions to climate change and marine acidification; requesting the Scientific Committee to continue to monitor the activities on this topic and to liaise with other organisations, in particular the IWC; charging the Scientific Committee to review the timeliness of holding a targeted region-specific workshop on climate change within the next triennium, in cooperation with ACCOBAMS Partners and other relevant Organisations, and to continue its works on studies of climate change and the impacts of other environmental changes on cetaceans as appropriate; and mandating the Agreement Secretariat to forward this Resolution and the works of the Scientific Committee and of the ACCOBAMS Partners to the relevant bodies and meetings.

The Red Sea

The northern Red Sea hosts native populations belonging to at least seven species of Delphinids (*Stenella longirostris, S. attenuata, Grampus griseus, Tursiops truncatus, T. aduncus, Sousa chinensis, Pseudorca crassidens).* Non-climate related threats include occasional direct killings, disturbance from tourism, and oil pollution. The ecology of Red Sea cetaceans has been investigated very little in the past; a three-year project funded by Italy, involving population studies through line-transect surveys along the coastal waters of Southern Egypt, is currently ongoing and will provide a first baseline on numbers and distribution of the main species.

During discussion the workshop noted that these are already highly specialized and extreme environments exhibiting high temperatures and, for the Mediterranean and Red Seas an oligotrophic regime. The level of speciation in some areas, notably the Black Sea indicates that populations have already been resident for a long time and have adapted to deal with changes from previous climate-driven events. The workshop suggested that the harvest of cetaceans in the Black Sea which took place up until the 1980s may yield interesting data on historic distributions and abundances. However for the Red Sea there is an almost complete lack of information on cetacean distribution and abundance.

Although cetacean surveys have taken place in the Mediterranean Sea, the lack of long term data sets prevents understanding of past responses to temperature fluctuations and to associated changes in productivity and the circulation regime. Changes to the circulation regime in the Mediterranean are well known, and include e.g. a shift in the winter production of deep water from the northern Adriatic Sea to the northern Aegean. Additionally the damming of the river Nile at Aswan had a major change on the amount of freshwater and nutrients flowing into the eastern basin of the Mediterranean.

Consideration was given to the planned ACCOBAMS climate change workshop and the Vienna workshop **recommended** that a theme of oceanography would be advantageous to help understand future changes in cetacean distribution. The workshop noted the unique temperature regime in the Red Sea which has a temperature profile in excess of 20°C from the thermocline right down to the seafloor in excess of 2,000m depth and suggested that comparison with this area may also be beneficial in understand cetacean response to climate related warming.

3.4.3.4 SUBMARINE CANYONS

Smith introduced this topic. The steep topography of submarine canyons induces upwelling that supports elevated cetacean diversity and abundance compared to surrounding waters (e.g. The Gully in eastern Canada; Hooker *et al.* 1999). These areas may also be important refuges for cetaceans and their prey when biological production elsewhere is reduced by oceanographic perturbations (e.g. the submarine canyon of Monterey Bay, California, during the 1997-98 El Niño; Benson *et al*. 2002). Submarine canyons are also major hotspots of biological production and fisheries catch (Breaker and Broenkow 1994; Sobarzo *et al.* 2001). The warming trends associated with human-induced climate change will be greater over continental interiors compared to oceans causing strong convection winds that may result in increased upwelling and nutrient availability in coastal waters associated with steep bottom topography. However, increased thermal stratification and a deepening thermocline could also prevent nutrient-rich waters from being upwelled (Roemmich and McGowan 1995; Harley *et al*. 2006). The refuge role of submarine canyons may be especially important for protecting cetacean populations from extirpation in ecological cul-de-sacs, such as in the northern Indian Ocean, where northern range shifts to cooler waters in response to warming ocean temperatures are impossible due to the geographic barrier of the Asian continent.

The Swatch-of-No-Ground (SoNG) is a submarine canyon in the northern Indian Ocean that supports a fairly well described cetacean fauna including one of the largest known populations of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) (Smith, unpublished), a possibly resident population of Bryde's whales (small form, *Balaenopta edeni*) and large groups of spinner and pantropical spotted dolphins (*Stennela longirostris* and *S. attenuata*, respectively) (Smith et al. 2008). The submarine canyon is the focus of a proposal to establish a transboundary protected area for cetaceans between Bangladesh and India.

The Workshop **agreed** that the SoNG offers an ideal opportunity for evaluating the potential role of submarine canyons as ecological refuges from the impacts of warming ocean temperatures. The objectives of this case study would be to: (1) Carry out a literature review on cetacean diversity and abundance in submarine canyons and on changes in their species composition and density resulting from seasonal or episodic warming events; (2) Conduct additional photo-identification and line-transect surveys of cetaceans in the SoNG for developing baseline estimates of abundance, movement patterns and survival (3) Model the preferred habitat conditions of each species using environmental data derived from satellite imagery or collected during extensive, systematic field surveys, which encompass a sufficiently large area and surrounding waters and range of environmental variability for habitat preferences to be detected; (4) Use ocean temperature and current scenarios derived from climate change models and information on the types of habitat selected by cetaceans in the SoNG to develop predictive models of climate related impacts on species abundance, survival and fine-scale distribution; (5) Use the habitat characteristics of other deep-water cetaceans in the northern Indian Ocean to predict whether or not new species may shift their range to occupy the SoNG as an adaptive response to warming ocean temperatures; and (6) Develop a low-cost, robust system for monitoring the species occurrence, fine-scale distribution, abundance, survival and health of cetaceans in the SoNG as a means for testing predictions on the implications of climate change in the northern Indian Ocean.

In discussion the workshop noted that additional species may be expected to move into canyon areas during periods of climate related change and discussed the maximum carrying capacity of such areas. This is a function not only of the size of the local population, but also of the length of time additional species are resident. For example, elevated carrying capacities have been observed under annual scale fluctuations such as those observed under El Nino events. The workshop recognized that the level of productivity supported by a canyon depends on individual physical oceanographic factors (e.g. the orientation of the canyon in relation to the prevailing winds that cause upwelling). Collaboration with oceanographers is necessary to fully understand the role of canyons in supporting cetacean populations, such as collaborative work with programmes such as the FAO Bay of Bengal Large Marine Ecosystems Project.

Canyons, as well as other hotspot areas such as seamounts and island archipelagos provide a multi-species habitat with different species occupying different spatial niches. This small scale distribution may in itself respond to climate related change, and the workshop noted that these small scale changes may be easier to study than the much larger range changes that are expected for the wider oceans. Around canyon areas such changes may also be observed in other biota including the distribution of fisheries which are relatively easy to study.

Recognizing the ecological and evolutionary importance of canyons the workshop discussed their role in species continuity. Over evolutionary time periods canyons may act as either genetic sources or sinks. In some parts of the world, notably in the Arctic Sea there are populations that are genetically isolated and these may have acted as reservoir or origin points for species during periods of past climate change.

The workshop **recommended** consideration of canyon and other areas of high biodiversity as marine protected areas (MPAs). Although changes in climate may cause change in the particular species resident in canyon areas, it is likely that the canyons would always support a high level of cetacean diversity and abundance. Climate-related change may allow canyons to act as natural refuge areas which continue to provide higher levels of productivity as food resources diminish elsewhere, such as observed for bottlenose dolphins at the SoNG. The workshop went on to **support** the proposed MPA designation for the northern end of the SoNG, although the workshop also noted that the boundaries of the proposed area overlap with the national border between India and Bangladesh. The MPA would need to be a multi-use designation due to the importance of fisheries in the area.

3.4.4 Range changes

3.4.4.1 CURRENT AND FUTURE PATTERNS OF MARINE MAMMAL BIODIVERSITY

Kirstin Kaschner joined the workshop via Skype and presented on current and future patterns of marine mammal biodiversity. She highlighted that quantifying the spatial distribution of taxa is an important prerequisite for the preservation of biodiversity, and could provide a baseline against which to measure the impacts of climate change. In a recent study (in prep), patterns have been analysed of marine mammal species richness, based on predictions of global distributional ranges for 115 species, including all extant pinnipeds and cetaceans. An environmental suitability model specifically designed to address the paucity of distributional data for many marine mammal species was been used. Richness patterns were generated by overlaying predicted distributions for all species; these were then validated against sightings data from dedicated long-term surveys in the Eastern Tropical Pacific, the Northeast Atlantic and the Southern Ocean. Model outputs correlated well with empirically observed patterns of biodiversity in all three survey regions. Marine mammal richness was predicted to be highest in temperate waters of both hemispheres with distinct diversity hotspots around New Zealand, Japan, Baja California, the Galapagos Islands, the Southeast Pacific, and the Southern Ocean.

The model was then applied to explore potential changes in biodiversity under future perturbations of environmental conditions. Forward projections of biodiversity using an intermediate Intergovernmental Panel for Climate Change (IPCC) temperature scenario predicted that projected ocean warming and changes in sea ice cover until 2050 may have moderate effects on the spatial patterns of marine mammal richness. Increases in cetacean richness were predicted above 40° latitude in both hemispheres, while decreases in both pinniped and cetacean richness were expected at lower latitudes. The workshop noted that the results demonstrated how species distribution models could be applied to explore broad patterns of marine biodiversity worldwide for taxa for which limited distributional data were available. Kaschner also highlighted the potential utility of AQUAMAPS (www.aquamaps.org), an online species distribution modelling tool, which currently covers more than 11,500 species and which includes a basic utility that allows the investigation of potential temperature increases on marine large scale species distributions.

In the ensuing discussion it was further noted that while predicted overall losses and gains of numbers of species might even out in certain areas, this did not mean that these impacts were not cause for concern. For example, if the loss of polar species was accompanied by an influx of an equal number of temperate species in the same region, the biodiversity loss and disruption of the ecosystem was still a reality. Kaschner stressed that model outputs need to viewed with some caution, since it should also be borne in mind that the predictions of the model were only based on two environmental variables, sea ice and sea surface temperature, and did not take other factors into account, such as prey availability, potential loss of breeding habitat in other regions, effects on food webs, species competition or changes in human behaviour. Another caveat concerned the spatial resolution of the IPCC models, which did not allow robust predictions for species with restricted ranges. Kaschner also noted that there was also uncertainty related to the level of tolerance for temperature changes for individual species. The model assumed rigid reactions to temperature changes, whereas in reality animals may not be equally sensitive to minor changes in temperature.

3.4.4.2 DISTRIBUTION OF COMMON DOLPHIN IN BRITISH SHELF WATERS

Colin MacLeod presented via Skype on ‘Water Temperature and the Distribution of Common Dolphin (*Delphinus delphis*) in British Shelf Waters: A Potential Indicator of Climate Change Impacts’. The presentation showed the results of a meta-analysis of fixed transect surveys in 8 study areas with respect to occurrence of common dolphins, some of which, especially in northern areas, had shown a rapid increase in sightings over the study period. In order to obtain a longer time series, the study had also correlated sea surface temperatures recorded in the British North Sea with stranding records of common dolphins.

MacLeod’s key conclusions were:

(1) Cetacean species ranges seemed to be linked directly to water temperature through their physiology, rather than indirectly through their prey as the prey distribution extended further north than the cetacean distribution, particularly at the pole-ward cool water limit of species distribution.

(2) At the warm water end of their range, the link between distribution and temperature was also often influenced by competition from warm water species, which could limit a species occurrence at temperatures below its upper physiological limit.

(3) Accordingly, predicting expansions of ranges under climate change was easier to do than predicting range contractions.

(4) Species which were limited to cooler waters (including temperate waters) were most at risk. This was especially the case for those also limited to shallow shelf waters, which had discontinuous distribution around the world, meaning that populations could not necessarily simply shift pole-wards due to the presence of deep water barriers to dispersion. This included several cetacean species, such as about half of species within the genus *Lagenorhynchus*, the genus *Cephalorhynchus* and also the majority of species in the family Phocoenidae. These species were probably the small cetacean species which were at greatest risk from range changes resulting from climate change (MacLeod 2009).

Figure 3: Predicted distribution of common dolphin based on projected Alb scenario SST data for the years 2020-2029 (A), 2040-2049 (B) and 2060-2069 (C). White shading indicates unsuitable habitat (likelihood of occurrence <0.25), pink shading indicates marginal habitat (likelihood of occurrence between 0.25 and 0.30), and dark red shading indicates core habitat (likelihood of occurrence >0.30). From Lambert et al. In Prep.

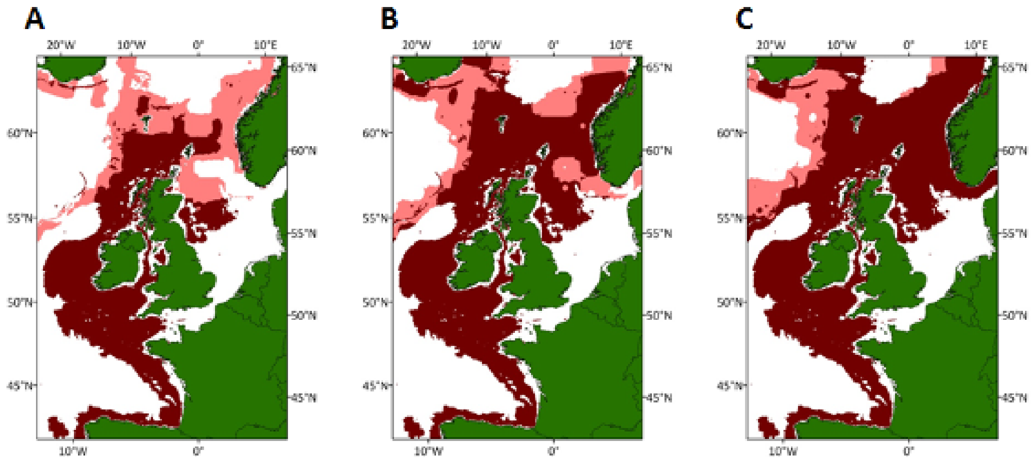
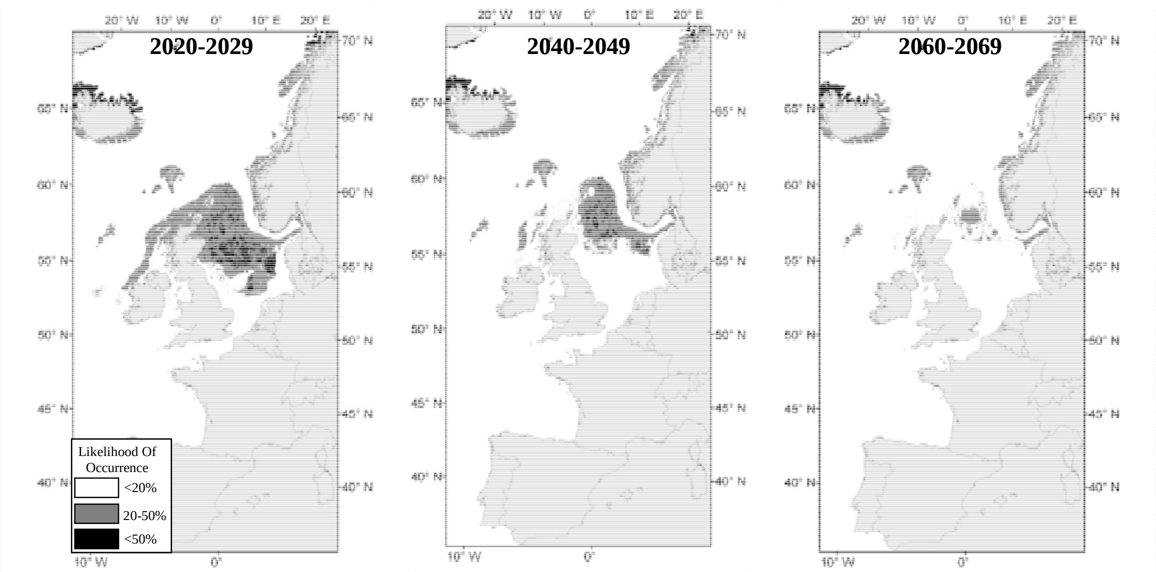


Figure 4: Predicted distribution of white-beaked dolphin based on projected Alb scenario SST data for the years 2020-2029, 2040-2049 and 2060-2069 (Lambert and MacLeod, pers comm.).



Bjørge noted that the white-beaked dolphin is observed more abundantly in the northern part of their range in Norway. There is as yet no evidence of an actual expansion of the range northward, but a clear shift of distribution within the existing range of the species. In contrast to the thermal limit hypothesis proposed by MacLeod and co-workers for common dolphin range expansion, Bjørge and his teams' findings - that while most white-beaked dolphins remain south of the polar front, many sightings were further north - suggested an ecological limit to northern range expansion in this species. Simmonds and Eisfeld (2010) provide a brief review of range changes in the north-east Atlantic. Rojas-Bracho confirmed that similar shifts had been observed in Pacific white-sided dolphins in the south-western Gulf of California (Salvadeo et al. 2010).

Bjørge added that a dramatic range expansion, such as the one predicted by MacLeod for the common dolphin, would mean this temperate species would enter into the range of high arctic species, potentially bringing with it pathogens new to this environment, to which resident species had no immunity.

Palacios noted that IPCC-class models are global but of a coarse resolution, and hence they are most appropriate to investigate large-scale (e.g. ocean-basin) phenomena, therefore caution needs to be applied when using these products to draw inferences about species responses and regional and local scales because IPPC model output is not reliable at these scales, especially in coastal regions where parameterisations are particularly deficient.

3.5 Other topics

3.5.1 Populations at the edge of their ranges and 'cul-de-sacs' (land and other barriers to migration or movement)

See preceding sections.

3.5.2 Health considerations

Jepson introduced the topic and Gulland joined the discussion via Skype. Disease was defined as "any departure from normality" and health was an "absence of disease". The Workshop noted that "health" is influenced by many complex interactions including immune status, body condition, pathogen exposure, pathogenicity of pathogen, toxicant exposure (inc. biotoxins and POPs) and environmental conditions. It was noted that disease can have population level impacts mediated by changes in (a) fecundity, (b) survival and (c) dispersal. Much uncertainty existed regarding the potential health effects of climate change on small cetaceans (Burek et al. 2008). Effects were likely to vary across species and habitats. The Siena workshop had highlighted specific concerns in Arctic/Antarctic species and species in coastal, inshore and shallow habitats including rivers and estuaries (IWC, 2010).

The Workshop recognized that Arctic species might be particularly vulnerable to direct and indirect effects of climate change (Burek et al. 2008). Direct effects included loss of sea ice, increases in water/sea temperature and an increased incidence/severity of bad weather. Indirect effects included changes in pathogen exposure, effects on body condition (via prey availability), changes in exposure to toxicants (e.g. biotoxins or POPs) and increased human habitation (run-off, shipping, etc). Baseline data on marine mammal health parameters (pathogen exposure/effects, diseases and toxicant effects), population trends and environmental conditions was considered essential in order to evaluate effects of climate change. Although some work had been done on pathogen and contaminant exposures, such long-term datasets were frequently lacking in many Arctic and non-Arctic marine mammal species. The Workshop **recommended** that baseline data on health parameters (including body condition), prevalence and intensity of pathogens, effects of toxicants, modes of disease transmission, host specificity, temporal and spatial patterns in diseases, and the relationship to environmental factors was needed to understand the potential effects of climate change on small cetacean health. These data must be integrated with long-term demographic data to determine whether effects of diseases and toxicants are significant at the population level.

Discussion moved on to consider the potential impact of climate change and warming seas on coastal species in shallow water habitats. The Siena Workshop had identified three temperature-related hypotheses relative to small cetaceans: 1) small cetaceans would redistribute to avoid thermal stress where possible, 2) modification of ecosystem structure and productivity would lead to changes in cetacean distribution to meet trophic demands, and 3) species in restricted habitat with little or no capacity to redistribute would be exposed to thermal, nutritional, and health-related stress. The common bottlenose dolphin (*Tursiops truncatus*) was a model species for investigating these hypotheses, as the species included examples of both redistribution and restricted movements in apparent response to large-scale environmental changes. Identifying the factors leading to these responses, and the biological consequences of the responses, could help in the development of predictions for other coastal small cetaceans under similar circumstances, and could help to guide wildlife management action. Comparisons of multiple sites differing in selected stressors could provide opportunities for controlled experiments. Diseases associated with immunosuppression and stress (e.g. lacaziosis in bottlenose dolphins or cetacean herpes virus infections) might be good indicators of environmental stress and linked to climate change.

Changes in coastal dolphin habitats in temperate waters might be more subtle than changes for polar species such as reduction in ice coverage, but hints about potential impacts from, and responses to, climate-related habitat changes were available from opportunistic observations and systematic long-term studies of bottlenose dolphins. At the extremes of the species' range, bottlenose dolphins had exhibited behavioural plasticity, through short- and long-term range shifts correlated with changes in water temperature. Range shift options might be limited for locally-resident, multi-decadal, multi-generational communities located well within the species' range, where adjacent waters were already occupied by other similar bottlenose dolphin communities. Dolphin communities living in these ecological cul-de-sacs, remaining in warming waters, might experience thermal stress, changes in their prey base, and increased exposure to pathogens, biotoxins, and environmental contaminants that might impact their survival and/or reproductive success. Findings from health assessments of bottlenose dolphins suggested that in combination, factors associated with warming waters might lead to cascading declines in individual health, but it was difficult to estimate the endpoint of such responses relative to population survival.

A number of field techniques and "natural experiment situations" exist for coastal bottlenose dolphins for potential detection of responses to climate change. Optimal application of these approaches require development of baselines and implementation of regular, systematic, long-term monitoring programs for species and populations selected as the most informative for potentially detecting impacts of climate change. The Workshop noted that small and fragmented bottlenose dolphins in UK (and other European) waters were at the northern extremity of their range and also exposed to levels of PCBs that greatly exceeded those associated with infectious disease mortality (as compared to acute physical trauma cases) in case-control studies of UK-stranded harbour porpoises (Jepson et al. 2005; Hall et al. 2006).

The Workshop **commended** the long-term studies on bottlenose dolphins in Sarasota Bay, Florida, USA. This system was undoubtedly the most comprehensive long-term study of cetacean sightings, strandings, reproductive and life histories, health parameters, nutritional status, chemical pollutant and biotoxin exposure, behavioural observations, prey distribution and abundance and long-term environmental changes and provided a unique basis for examination of possible climate change signals and effects for resident populations of small cetaceans in inshore waters. The Workshop **recognized** that the long-term Sarasota Bay bottlenose dolphin studies now had a very important global role in enhancing our understanding of the complex interactions between environmental, immune status, body condition, pollutant and pathogen exposure on the health and population viability of a coastal cetacean species. While it was possible to speculate based on existing knowledge of biology, ecology, physiology and medicine for some of the species, few direct data existed relating environmental parameters associated with climate change to cetacean health. Disentangling climate change parameters from other factors affecting cetacean health would be challenging. Conversely, it would also be important to understand linkages between climate change and other pervasive factors (e.g. POPs) that might lead to exacerbation of health or reproductive problems.

As a first step toward understanding health and reproductive impacts of climate change, the Workshop **strongly recommended** that appropriate existing data sets on the health of cetaceans (like Sarasota Bay) be examined to identify possible relationships with climate change parameters. The 2009 IWC Climate Change Workshop had identified long-term data sets for bottlenose dolphins that might be subjected to rigorous quantitative analyses to test basic hypotheses, providing a starting point for developing hypotheses that might have broader applicability, and might help to guide climate change research. For example, it had been hypothesized that increasing water temperature might directly and indirectly affect the health and reproductive success of coastal bottlenose dolphins living in ecological cul-de-sacs by causing thermal stress, changing availability of circulating environmental contaminants, compromising immune function, changing exposure and responses to pathogens and harmful algal blooms, and changing the cetaceans' prey base (Wells 2010). Working with some of these data sets, a small team of biologists, veterinarians, and biometricians might be able to begin to identify the relative contributions of temperature-related and other factors to the health, body condition, survivorship, fecundity, and reproductive success of cetaceans.

The workshop **recommended** that the results of these preliminary analyses be used to establish a framework of hypotheses for further testing across study sites where specific parameters can be held constant, facilitating examination of targeted parameters. For example, recent health assessment research in the south-eastern United States had compared health parameters of bottlenose dolphin populations with different exposure histories to harmful algal blooms or POPs to the well-known reference population in Sarasota Bay, Florida to try to identify the health related effects of these stressors. Similar efforts, either taking advantage of existing data sets or developing new field studies to test specific climate change hypotheses, could be fruitful.

In terms of restricted shallow water habitats, the Workshop noted that river dolphins and porpoises were particularly vulnerable to the effects of climate change including adverse health effects. In respect of river dolphins there was often a mismatch between high conservation concern but only low research effort/funding. The recent likely extinction of the baiji was a notable example (Turvey et al. 2007). The Workshop **commended** the work presented at the workshop being conducted on river dolphins in Bangladesh and South

America and **recommended** that studies of freshwater cetacean population size and status be complemented with investigations of health (e.g. pathogen exposure) and pollutant exposure. Along with coastal bottlenose dolphins, similar studies should be conducted on other small cetaceans in potential ecological cul-de-sacs with high bycatch rates and pollutant exposures such as cetaceans in the Mediterranean and Black and Red Seas, Gulf of California and the Baltic Sea. The vaquita (*Phocoena sinus*) was a species with high conservation concern facing high rates of by-catch. Although not highly polluted, the potential effects of climate change on the vaquita were uncertain.

The Workshop noted that apart from bottlenose dolphins in US waters, long-term datasets also exist for species with high or relatively high pollutant exposures such as killer whales and St Lawrence Seaway belugas. Killer whales are thought to have the largest distribution of any cetacean species but low sightings/strandings rates appear to occur globally and this species might be particularly vulnerable to combinations of climate change and high pollutant exposure. Good long-term datasets exist for killer whales in the north-east Pacific and for belugas in the St Lawrence Seaway and the Workshop **recommended** that the distribution, abundance, health and pollutant exposure together with trends in climatic data should continue to be monitored (IWC 2006).

Good long-term large datasets also exist for harbour porpoises in the USA and Europe. The Workshop **recommended** that these data sets be used to facilitate comparison between health indices, disease, pathogen and pollutant exposures, genetic characteristics, life history and population demographics in different habitats with different or similar trends in climatic data. Such studies could include newer techniques in blubber lipid and reproductive/stress hormone analyses being developed by the NOAA Southwest Fisheries Science Center for small samples obtained remotely through standard darting techniques. These techniques could also be applied to a number of other small and large cetaceans.

The workshop **recommended** that climate change be considered as a potential causal factor when investigating Unusual Mortality Events (UMEs) and where animals are outside of their normal species ranges (small and large cetaceans).

3.5.3 Refuges

See section 3.4.3.4 on submarine canyons

3.5.4 Implications of Sea Level Rise

As discussed at the Siena workshop (IWC, 2010: section 3.5.1) declining freshwater flows and sea level rise would result in habitat reduction for the obligate freshwater Ganges dolphin. Declining freshwater flow will cause an upstream movement of salinity gradient, but additionally increased sediment deposition as a result of slower current flows would reduce key river confluence areas as they gradually become silted up. The study further showed that although the freshwater dependent Irrawaddy dolphins utilize a larger range of habitat than Ganges dolphin and may be able to move further into mangrove forest, they also showed a strong affinity for river confluence areas. Consequently habitat availability may also decline for Irrawaddy dolphins as these confluence areas silt up under decreasing freshwater flows. The limit to the upstream range of Irrawaddy dolphins may be constrained by inter-specific competition with the Ganges river dolphin.

The workshop **recommended** that utilising episodic or periodic natural events, such as the differences between seasonal rain fall or other unique occurrences can assist in providing insight as to the long term response options available to marine species.

For the Mediterranean, the coastal zone will be affected by human activities, especially around urbanised areas where pollution may increase. In the Red Sea, the coral reefs, sea grass beds and mangroves may be affected. Sea grass areas are nursery areas, so the effect will take place though it may not directly affect cetaceans. So for coastal urbanised areas cetacean habitat may be degraded. Sea level rise may also cause an increase in land reclamation projects.

For the vaquita there is no likely threat from urban development. Models show that sea level rise may allow an increase in possible habitat area.

The general research **recommendation**s from the workshop were there was a need for: (1) better information on habitat preferences for freshwater dependent and coastal cetaceans; (2) better information on nutrients and nutrient cycling under conditions of sea level rise; and (3) improved liaison with the oceanographic community to investigate sea level rise models, especially around estuaries and other areas which are known to be particularly dynamic.

3.5.6 Ocean Acidification

The workshop did not expect increasing ocean acidification to influence cetaceans directly, although it recognised that change to food chains, especially in relation to calcifying species and species with high metabolic activity such as cephalopods would be influenced. Habitats, especially coral reef habitat important for spinner dolphins would be affected. The workshop **recommended** undertaking a literature review of the effects of acidification on key food chain species for cetaceans.

3.5.7 Endangered Small Cetaceans

BAIJI

Although the demise of the baiji has not been related to climate change, the workshop considered it as case study and Rojas-Bracho presented a brief review: in November-December 2006 an international team of scientists had carried out an intensive six-week multi-vessel visual and acoustic survey that covered the entire historical habitat of the baiji in the main Yangtze channel. The survey failed to find any evidence that this species survived and it was concluded that the baiji was functionally extinct (Turvey et al., 2007). A range of anthropogenic risk factors had been implicated in the baiji's extinction, among them boat collisions, pollution and habitat loss from water development, but the primary factor was probably unsustainable bycatch in different types of artisanal fishing gear, like rolling hooks, nets (gillnets, fyke nets) and electro-fishing. The baiji was the first cetacean species to become extinct by human activities. Immediate and extreme measures might be necessary to prevent the extinction of the sympatric Yangtze River population of finless porpoises that is also experiencing a rapid decline (Zhang et al. 2003) in the continuously deteriorating Yangtze ecosystem.

The workshop participants next explored the question why the finless porpoise, which also inhabits the Yangtze River, was not equally affected as the baiji. Its population numbers are also thought to be in decline, even though only rough estimates exist, but the situation is not as dramatic and it is classified as vulnerable on the IUCN Red List. Smith and Wells explained that the species, while more or less sympatric in range, has different habitat preferences and feeding strategies. The main fishing methods in the river (rolling hooks and electric fishing) posed a greater danger to bottom-feeders like the baiji, who have an affinity to deep pool areas. Further, the baiji's near shore preference made it more susceptible to habitat degradation or loss resulting from the construction e.g. of flood gates in confluence areas, its the primary habitat. In contrast, the finless porpoise probably stay more in the channel and is less specialised than baiji. The finless porpoise also has a different life history pattern, with a significantly faster turnover than the baiji.

It was noted that due to the long time gap between surveys, the reasons for the dramatic decline of the baiji were never investigated properly before the animals went extinct. However, when comparing the two species, the finless porpoise appears to have more resilience to deal with impacts of water development (Smith and Reeves in press). Overall, it seemed likely that the extinction of the baiji was caused by a combination of direct and indirect threats and interactions of these, such as a degradation of the habitat, causing a lower prey availability, which in turn increased baiji predation off fish hooks, leading to a higher bycatch threat.

VAQUITA

The vaquita is considered the most endangered marine mammal species and the one with the most restricted distribution. In 2008 vaquita abundance was estimated to be 245 animals (CV=73%, 95%CI 68-884). This estimate is 57% lower than the 1997 estimate, which implied an average rate of decline of 7.6% per year due to incidental mortality in gillnets (Gerrodette et al, *in press*).

Since the Gulf of California is a semi-enclosed habitat, which does not give the species the opportunity to adjust its range northwards should environmental conditions be altered due to climate change, the question was raised whether this would pose an additional conservation problem to the vaquita. It was not clear how close the species is to its thermal limits and how the species would respond to increasing habitat temperatures, especially with respect to the degree to which they would be able to adjust or acclimatize to warming conditions. The vaquita deviates from most other phocoenids in its ability to tolerate seasonal water temperature fluctuations. (Silber, 1990; Rojas-Bracho et al., 2006)

Although a statistically significant warming of ~1°C was observed in the Gulf of California from the mid-eighties to 2000 (apparently within the inter-decadal variability of the Pacific Ocean) the recent trends were unclear. Beyond inter-annual variation, analyses were extremely difficult within the Gulf of California region because of a general lack of long time-series observations or ecological proxies and very few locally measured physical variables. Modelling approaches were not easily adopted since in general terms global databases and circulation models do not resolve the Upper Gulf of California geographic scale (Lavin et al., 2003; Lluch-Cota et al., 2007, Lluch-Cota et al., *in press*).

BALTIC HARBOUR PORPOISE

Deimer-Schuette noted that the case of the vaquita shows parallels to that of the genetically distinct Baltic population of the harbour porpoise which is also considered critically endangered and lives in a largely enclosed sea. Also for this population, bycatch is clearly the most significant threat, even though other factors such as pollution are likely to have an impact. The workshop **commended** ASCOBANS for their recovery plan (known as the *Jastarnia* Plan) and **recommended** investigating the anticipated temperature-related changes to the Baltic Sea ecosystem in relation to its suitability as habitat for harbour porpoises. Bjørge expressed concern that increased run-off due to climate change will exacerbate the threats to Baltic harbour porpoises. These threats include increased pollution mobilisation, enhanced eutrophication with an increased risk of toxic alga blooms and expansion of the anoxic areas.

4. IDENTIFICATION OF KEY ASPECTS

4.1 Key Studies

Key studies have been identified in the preceding sections of this report and, in addition, the workshop also some lessons concerning climate change-related conservation management of cetaceans as follows:

(1) Artificially modified environments, such as dammed rivers, lower the resilience of the habitat and the response options of the species (Nilsson et al. 2005), making populations more vulnerable to climate change effects.
(2) The situation in the wider area (e.g. the entire river basin) needs to be taken into account and those factors identified that impact the habitat at large, along with factors causing direct mortality.
(3) Tertiary effects of climate change need to be considered, which may be specific to each case.
(4) Modelling exercises should aim to separate the potential impact of climate change-related stressors from other threats and should strive to identify linkages between climate stressors and other stressors, e.g. contaminants and thermal stress.
(5) Climate change impacts must be evaluated on a population by population basis, as each situation is unique in terms of requirements, resilience and adaptability of the species. However lessons from one population may be valuable in understand changes in other populations

4.2 Key species, populations and areas

See preceding sections

4.3 Opportunities for future research

See section five.

4.4 Ongoing work streams

See section five. In addition a working group was established to liaise with modelers on the development of modelling studies to help elucidate the effects of climate change on cetaceans. The working group consists of O'Cory-Crowe (Convener), Wells, Smith, Ritter and Palacios. Its terms of reference are to:

1. Identify the (biological) questions that may be examined by quantitative analyses and modelling exercises, and develop testable hypotheses.

2. Give emphasis to comparative approaches across sites/populations and species

3. Aim to help develop a "standardized" suite of methods

4. Consider the utility of oceanographic data-sets (e.g. SST, current systems/dynamics, chlorophyll)

The working group was also asked to help clarify two questions:

- What are the minimum and specific data requirements, time series, resolution, etc. required and

- How can we use extant data sets to maximum effect?

This group was requested to report to the IWC Small Cetaceans sub-committee at its meeting in 2011. The potential relevance of the work of the Ecosystem Modelling Subcommittee of the Scientific Committee was noted.

5. CONCLUSIONS AND FURTHER RECOMMENDATIONS

5.1 Further research and post-workshop consultations

5.1.1 Restricted habitats

Some populations of small cetaceans may not be able to relocate to cooler or otherwise more favourable environments under climate change scenarios due to a lack of suitable habitat. This may be because they have a naturally small distributional range (e.g., vaquita, Maui dolphin); because they have very narrow habitat requirements (e.g., restricted to the continental slope, around seamounts or submarine canyons); because of physiographic or oceanographic barriers (e.g., the Mediterranean Sea, the Black and Red Seas, the Gulf of

California, the northern Indian Ocean); or because potentially favourable habitats are already occupied by competitors (i.e. the so called 'ecological cul-de-sacs' as for example behavioural exclusion among adjacent dolphin communities resident to specific bays). These are all examples of *restricted habitats* that deserve particular attention because populations inhabiting them may be exposed to thermal, nutritional and health related stress, and eventual disappearance. Although this issue was identified during the Siena Workshop (CC2), it was revisited during this Workshop in order to more clearly define the various kinds of restricted habitats. This Workshop **strongly recommended** a global review of restricted habitats for small cetaceans be conducted to gain a better picture of their occurrence, and **encouraged** focused studies to investigate the various dynamics taking place in restricted habitats in relation to changing environmental conditions, including the circumstances under which 'cul-de-sacs' are formed or when they may cease to exist. A working group was established to initiate the project consisting of Smith, Simmonds, Wells, Rojas-Bracho and Palacios. The working group will report back to the Scientific Committee in 2011.

5.1.2 Global hotspots and range shifts

The Workshop **commends** the work presented using IPCC model projections to predict possible shifts in cetacean distribution and diversity in response to climate change. For species with restricted ranges and for regional studies, the Workshop **encourages** collaborations with the oceanographic community to obtain output from 'downscaling' modelling studies (i.e., locally parameterized circulation models using IPCC scenarios as input to obtain high-resolution predictions) as more appropriate products for species that may be of particular concern. The workshop recommends exploring possible collaboration with the IPCC on issues relevant to cetaceans.

Localized areas with high species diversity (i.e., biodiversity hotspots) may be useful as indicators of climate-induced change. Since species have particular ecological demands and organize themselves along environmental gradients, changes in temperature, phytoplankton abundance and other environmental variables might lead to subtle, but detectable changes in relative abundance or other community attributes over time. The Workshop **encourages** studies relating multi-species habitat requirements to observed shifts in environmental factors at biodiversity hotspot sites, so as to identify processes induced by climate change, for example in the Canary Islands where a suitable long term data sets exists.

5.1.3 Health Implications

The Workshop **recommends** investigation of health impacts, exposure to toxins and to quantify stress and fecundity from hormones in blubber samples (as per SWFSC recently developed techniques and Kellar et al., 2006) in populations where there is evidence of range compression, which may result in increased conspecific and/or interspecific competition. This will facilitate relating population parameters to health and reproductive parameters.

New strategies specifically aimed at detecting the potential impacts of thermal stress on small cetaceans are needed. In this regard, the Workshop **suggests** that case studies be facilitated in areas such as the Red Sea, where the very warm, nearly isothermal water column currently resembles an ocean altered by global warming, providing a unique opportunity to examine community structure parameters (e.g., density, spatial segregation and vertical niche partitioning) that might provide insight into expected responses by other tropical cetacean communities in future years.

5.1.4 Arctic

It was noted that longitudinal studies on populations of small cetaceans that span multiple generations, such as the investigations of bottlenose dolphins in Sarasota Bay and beluga whales in the St. Lawrence Estuary, provide the necessary temporal scale, individual variability and quantitative power to assess impacts of climate-related changes in the environment on individual behaviour, reproductive success and survival. These insights in turn are required to assess population and species-level impacts. This Workshop **recommends** similar long-term studies on small cetaceans, including endemic beluga whale and narwhal, through individual's lives and across generations in Arctic waters to determine the impacts of climate change on individual fitness, population viability and species adaptability.

The observed climate-related changes in Arctic marine ecosystems, including sea-ice loss, increased sea surface temperatures and changing weather patterns are predicted to influence the distribution, population dynamics and foraging ecology of small cetaceans in Arctic systems, with some effects already being evident. While changes in species ranges and population trajectories are among the initial observed responses, the Workshop underscores that increased predation and competition from temperate species expanding northward are also expected, as are changes in prey communities, primary production and nutrient cycling. Thus, the Workshop **recommends** research on how climate influences predator-prey interactions, competition and trophic relationships of small cetaceans in Arctic marine food webs.

Considering the rapid and widespread disappearance of Arctic sea ice and the dependence of beluga and narwhals on it, the Workshop **recommends** that a global assessment of these two species be conducted as a matter of priority, including investigation of their habitat preferences, as this will inform how they may respond to habitat changes.

Consideration could be given to extension of the indices presented in Laidre et al. (2008) for the Arctic to other ecosystems. This could include the indices more recently developed by Alter et al. (2010).

The Workshop did not explicitly address Antarctic small cetaceans, but notes that the Southern Ocean Research Partnership will consider climate change issues and small cetaceans (e.g. killer whales).

5.1.5 Freshwater-dependent cetaceans

As noted in section 3.4.3.2, the Workshop **recommended** that a comprehensive assessment be conducted on the implications of climate change on freshwater-dependent cetaceans. This assessment should include an emphasis on upstream-downstream connectivity, prey availability and climate related impacts to critical habitat including appended lakes, flooded forests and channel confluences. An additional component of the assessment should be an evaluation of potential options for mitigating the direct impacts of climate change on rivers with existing water engineering structures as summarized in section 5.2.1. The Workshop also suggested that existing information on historical hydrological records and time series of fisheries catch be compiled so that long-term trends can be detected.

5.1.6 Whale-watching

It was noted by the workshop that some whale and dolphin watching activities could provide the opportunity to monitor cetacean populations and their responses to changing climate. It was further noted that whalewatching contributes significantly to the income of some local economies. The workshop **recommended** that the impact of climate change on dolphin and whale-watching operations should also be assessed by conducting socio-economic evaluations and modelling, especially in regions where environmental changes are already ongoing. See also Lambert et al. (in press).

5.1.7 Miscellaneous

Bjørge noted that changing weather problems may alter the dynamics of ice formation in fjords of western Norway. The winter precipitation used to be snow and the winter run-offs were minimal. In recent years higher temperature and stronger Atlantic low pressure systems produce winter precipitation as rain and the winter flooding may establish a freshwater top layer on the fjords. After the passage of a low pressure system, the wind calms and the temperature drops rapidly. In hours, the fjords can be covered by ice with an increased risk for entrapments of porpoises. Such entrapments with mortality of porpoises have been documented in Sognefjord. The workshop **recommended** that this should be monitored.

5.2 Conservation Implications and responses

The workshop considered the conservation implications of climate change for small cetaceans, noting that, generally, climate change effects would be expected to exacerbate the impacts of other stressors.

The workshop stressed the need for clear conservation objectives to be set and considered that status indicators that could be monitored over time (such as those developed for the EU Marine Strategy Framework Directive) could be helpful. It **recommended** that conservation objectives be set on a population basis where possible. Where population structure is unclear, a regional approach might be taken and it was noted that different management regimes would need to be developed for different situations.

Similarly, it was **agreed** that Marine Protected Areas are a useful tool in addressing climate changes, but it was stressed that they would need to be adaptable and adequately large to allow for responsive movements of cetaceans (in effect the workshop noted that they were part of a suite of available responses). MPA networks, should include corridors and critical habitat areas. The workshop **recommended** that better information should be gathered on how these areas might change in the future and a synthesis of existing information. One factor that may be important in selecting MPAs for cetaceans could be ‘ecological resilience’ (i.e. that some areas are less vulnerable to the effects of climate change than others and might, therefore, maintain suitable habitat in the medium term in the context of climate-related changes; one possible example being submarine canyons).

Marine spatial planning tools such as those being developed in the EU (i.e. in the *Integrated Maritime Policy*) and in North America (e.g. in the *US National Policy for the Stewardship of the Ocean, Our Coasts and the Great Lakes*) were identified as a suitable mechanism to support cetacean conservation.

The workshop also commented on the need for consistent application of standards for marine resource exploitation and management worldwide, otherwise problems might be moved from more restrictive management regime to those that are less regulated. Another general concept that was noted was that the approaches identified so far often required underpinning by the sharing, in a timely and transparent fashion, of relevant data. In many regions, small cetacean conservation (or marine conservation and management more generally) also urgently requires international collaboration (for example in the Bay of Bengal which has a disputed border).

The workshop **encouraged** skill-sharing with respect to marine management tools with less developed countries. It also noted the work of Convention on Biological Diversity in trying to address high seas issues, including critical habitat via the development of an appropriate legal framework.

The workshop **recommended** that, in the face of climate change, all intentional removals of small cetaceans should be carefully managed via precautionary quotas which should allow for the effects of climate change.

5.2.1 Conservation Recommendations for freshwater cetaceans

With respect to freshwater cetacean conservation**, t**he Workshop **stressed** that there may be few options available to prevent or mitigate the direct impacts of climate change on marine cetaceans, however, possibilities for freshwater-dependent species could include manipulation of upstream flows using existing water engineering structures to maintain suitable salinity gradients in estuaries and preserve essential habitat features, such as bars and mid-channel islands that induce counter-currents, in rivers. Other ecosystem-based interventions that could be made in river systems already affected by water developments could include dam removals, re-vegetating damaged areas to temper peak flow releases, removing or setting back levees to restore lateral connectivity to floodplains, and reconfiguring channels to increase water retention or correct past channelization (see also CC4).

5.2.2 Conservation recommendations for Arctic species

The workshop noted that developments in the Arctic could be characterised as a new marine area now being subject to unprecedented exploitation using new technologies, following ice retreat. Whilst this constitutes a significant concern it also offers the potential for the development of an exemplary multi-national and multi-stakeholder management regime. The workshop discussion was informed by a letter from WWF (one of the sponsors of the workshop) which identified some conservation actions.

The workshop **recommended** that:

(1) Baseline studies should be undertaken prior to economic activity within the species' ranges;

(2) The effects of seismic exploration and shipping should be comprehensively assessed before expansion of these industries occurs;

(3) The cumulative impact of economic activities across sectors (e.g. fisheries, shipping, oil & gas development, hunting and tourism) should be assessed; and

(4) Integrated cross-sectoral management plans should be developed which will secure healthy ecosystems and protect biodiversity, and are based on the precautionary principle.

5.2.3 Consideration of IUCN Red List designations

The workshop **commended** the ongoing work by the IUCN to integrate climate change into the elaboration of its Red List designations (IUCN 2010). It was noted that climate change impacts had not been considered in the last (2008) review of cetaceans and the workshop **recommended** that a re-evaluation of cetaceans be initiated in a timely manner. There is a need for better understanding of the population structure of many species and the predicted impacts of climate change on them. The voluntary nature of participation of experts in such reviews was noted and some participants wondered if this process might be expedited by funding a consultant to help facilitate it.

The workshop made a draft list of priority species and populations and **invited** the Small Cetacean Subcommittee of the IWC to review, refine and prioritise this:

- Finless porpoise – Populations in Yangtze, SE Asia, Indian Ocean because of low population sizes and bycatch.
- Irrawaddy dolphins – with a special emphasis on freshwater populations because of restricted habitat, bycatch issues and high likelihood of climate change impacts in their environments.
- Franciscana – because of high bycatch throughout its range.
- Hector’s and Maui dolphin – because of small population sizes and bycatch.
- *Inia* spp – because of deliberate killing and climate related stressors.
- *Platanista* sp (Ganges and Indus River dolphin) – because of bycatch, climate and water development related stressors.

- Guiana dolphin – because of fragmented distribution, vulnerability to sea level rise and bycatch.
- Common bottlenose dolphin (Black Sea sub-species and elsewhere) – restricted range, climate related stressors, pollution, bycatch and directed take in Black Sea.
- Short-beaked common dolphin (Med population) – because of restricted range, climate related stressors, pollution, prey depletion and bycatch.
- Indo-Pacific humpback dolphin (northern Red Sea and Taiwan populations) – because of lack of data, climate related stressors and restricted range.
- Harbour porpoise (Black Sea and Baltic population) restricted range, climate related stressors, pollution and bycatch.
- Vaquita – because of rarity, restricted range, bycatch and highly endangered status.
- Narwhal – because of rapid climate driven changes to ice habitat and small size of some populations.
- Beluga **–** because of rapid climate driven changes to ice habitat and small size of some populations.
- Orca - in view of low data, low stranding rates and high organochlorine exposures.
- White-beaked dolphins (the north-west Atlantic population) – limited distribution/habitat and rapid range constriction.

This list is intended to encourage re-assessment of some populations in the light of climate change and/or urgent assessment of the impacts of climate change on the status of some critically endangered species and populations.

Assistance in the process of re-evaluation of cetacean species and populations could come from the IWC Small Cetacean Sub Committee and the CMS scientific council, cetacean agreements and MoUs and their scientific bodies

5.2.3 Future workshops

The Mediterranean and Black Seas are regions where cetaceans will be unable to migrate away from climate driven changes and Notarbartolo di Sciara highlighted the potential opportunity provided by the planned ACCOBAMS climate change workshop to further determine the consequences of climate change for cetaceans there. The workshop **recommended** that significant contribution from the oceanography community should be sought at an early/planning stage, e.g., through the involvement of CIESM, to interface in greater detail with knowledge of past events and try to set up different ways of collecting data in the future. The workshop also **recommended** that consideration of the Red Sea should be included in the ACCOBAMS workshop, since oceanographic differences amongst the three regions could be used to evince insight. In particular the Red Sea currently offers a unique set-up for exploring the possible effects on cetaceans of climate change because of its worm, relatively isothermal water column that resembles an ocean altered by global warming. Hence, a study could be conducted in this region to examine the potential responses of this small cetacean community to thermal stress and derive insight into what we might expect to see in other tropical communities in future years.

5.3 Other

Finally the workshop **stressed** that all of its recommendations should only be considered stop-gap measures, designed to understand and mitigate the effects of climate change on small cetaceans. More appropriate and effective conservation action would be to eliminate anthropogenic sources of climate change at their roots.

6. ADOPTION OF REPORT

The report was adopted on 1st December subject to final editorial matters that would be handled by Brockington and Simmonds. The Co-Chairs of the workshop acknowledged Gruendler, Nouak and Stachowitsch for their great Austrian hospitality and said that the workshop participants appreciated the opportunities to experience the gastronomy and architecture of Christmas-decorated Vienna. The workshop gave their thanks to the rapporteurs and Co-Chairs and especially recognised Simmonds for his dedication, enthusiasm and energy in his role as Convenor.

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ANNEX B

Agenda

1. INTRODUCTORY ITEMS
   - 1.1 Welcome and Introduction
   - 1.2 Appointment of Officers
2. WORKSHOP OBJECTIVES
   - 2.1 Summary of Objectives
3. OVERVIEW OF EXISTING RESEARCH AND HYPOTHESES
   - 3.1 Report of IWC Second Workshop on Climate Change (CC2)
   - 3.2 Consideration of Hypotheses from CC2
   - 3.3 Consideration of Other Relevant Information, including Recently Published Reviews
   - 3.4 Key Presentations
     - 3.4.1 The Arctic Sea
     - 3.4.2 Barents Sea and adjacent areas
     - 3.4.3 Restricted Habitats
     - 3.4.4 Range changes
   - 3.5 Other topics
     - 3.5.1 Populations at the edge of their ranges and 'cul-de-sacs' (land and other barriers to migration or movement)
     - 3.5.2 Health considerations
     - 3.5.3 Refuges
     - 3.5.4 Implications of Sea Level Rise
     - 3.5.6 Ocean Acidification
     - 3.5.7 Endangered Small Cetaceans
4. IDENTIFICATION OF KEY ASPECTS
   - 4.1 Key Studies
   - 4.2 Key species, populations and areas
   - 4.3 Opportunities for future research
   - 4.4 Ongoing work streams
5. CONCLUSIONS AND FURTHER RECOMMENDATIONS
   - 5.1 Further research and post-workshop consultations
     - 5.1.1 Restricted habitats
     - 5.1.2 Global hotspots and range shifts
     - 5.1.4 Arctic
     - 5.1.5 Freshwater-dependent cetaceans
     - 5.1.6 Whale-watching
     - 5.1.7 Miscellaneous
   - 5.2 Conservation Implications and responses
     - 5.2.1 Conservation Recommendations for freshwater cetaceans
     - 5.2.2 Conservation recommendations for Arctic species
     - 5.2.3 Future workshops
   - 5.3 Other
6. Adoption of report

ANNEX C

List of Documents

SC/N10/CC

1. ANONYMOUS. Key studies for creating a scientific framework for understanding how climate change is likely to affect cetaceans.
2. MACLEOD, C. Key principles for creating a scientifically-robust framework for understanding, predicting and mitigating the impacts of climate change on cetaceans.
3. SMITH, B.D., STRINDBERG, S. AND MOWGLI, R.N. The potential role of submarine canyons as ecological refuges for cetacean diversity in a changing ocean environment: a proposed case study in an ecological cul-de-sac.
4. SMITH, B.C., REEVES, R.R. AND SONDEREGGER**,** C. Comprehensive assessment needed on the implications of climate change for freshwater-dependent cetaceans.
5. SKERN ‐ MAURITZEN, M. AND FALL, J. Dolphin densities and distributions in the Barents Sea and potential influences by the recent temperature increase.