Report of the IWC Climate Change Workshop

Virtual Meeting, 30 November-3 December 2021

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1. INTRODUCTIONS

The workshop was opened by Mark Peter Simmonds, the convener, who welcomed everyone, noting that many distinguished scientists from all around the world would be participating. A list of participants is given in Annex A. He noted that the workshop was originally conceived as an in-person meeting some two years ago but that the steering committee agreed to go ahead with a virtual meeting because of the pandemic. The aims for the workshop are to increase understanding of how climate change is affecting and will affect cetaceans, and how the IWC's science and stewardship mission can best address these challenges, in collaboration with other organisations. Simmonds noted that although the IWC does not have a direct role in the human activities that are contributing to the climate crisis, it can provide advice to relevant bodies on how their practices may affect cetaceans. This guidance could be provided, for example, to the International Maritime Organization (shipping), CCAMLR (conservation), as well as the FAO (fishing) and regional fisheries management bodies. On a national level, this could include matters related to offshore renewables, coastal construction in response to sea level change, and storm related pollutant run off from land-based sources. Simmonds identified four strands of potential advice and recommendations:

(1) describing how climate change is expected to affect different cetacean populations;
(2) considering how other management measures (for example to address threats) may need to be adjusted to take into account the additional pressures on cetacean populations resulting from climate change;
(3) describing how shifts in cetacean distribution as a result of climate change may bring cetacean populations into contact with different pressures compared to the current situation; and
(4) considering how changes in human activities as a result of, or to address, climate change may impact cetaceans.

In summing up his introductory comments, Simmonds, noted that he well recalled the first IWC workshop on climate change in 1996 and the disappointing workshop conclusion that our understanding and predictive powers were limited such that implications for cetaceans were not clear. He noted that this workshop comes at a time when the effects of climate change are being felt by human populations globally. People have been killed or lost their homes as a result of severe weather events outside of the norm and many of us now live in fear of what the future holds for our families, our communities and our ways of life. He asked the meeting to pause for a moment to show respect to the lost, the fearful and the distressed.

2. REVIEW OF TERMS OF REFERENCE AND AGENDA

Simmonds outlined the Terms of Reference for the workshop which had been elaborated by the steering committee into the agenda (see Annex B). The agenda was approved.

3. APPOINTMENT OF CHAIR AND RAPPORTEURS

Simmonds was appointed as Chair with Sarah McCain, Laetitia Nunny, Debbie Palka, Sarah Rice, Imogen Webster acting as rapporteurs and Iain Staniland acting as Rapporteur-in-Chief. The Chair noted that Leaper would also assist in collecting recommendations as the meeting progressed. Recommendations of this workshop are given in blue boxes, target key: C=Commission; CG=Contracting Government; G=General; R=Research (community); S=Secretariat; CC=Conservation Committee; SC=Scientific Committee.

4. PREVIOUS AND ONGOING WORK ON CLIMATE CHANGE UNDERTAKEN BY IWC

The reports of the previous IWC workshops on climate change and the IWC's previous recommendations were made available on the SharePoint site. The workshop's steering committee had reviewed the recommendations as part of the process of developing the agenda and these could be drawn upon as appropriate by the current workshop (see Annex C).

5. SUMMARY OF IPCC LATEST REPORT

Striegel presented a summary of the IPCC report noting anthropogenic climate change is rapid, widespread, and intensifying (Intergovernmental Panel on Climate Change (IPCC), 2021). Global warming of 1.5 or 2°C - the upper limit defined in the Paris Agreement - will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas

[1]Presented to the Scientific Committee meeting as SC/68D/Rep/01.

emissions occur. But even then, there are many changes due to past and future greenhouse gas emissions that will remain irreversible for centuries or even millennia, especially in the ocean. Examples include the melting of the Greenland and Antarctic Ice Sheets, global sea level rise, ocean warming, deep ocean acidification, and deoxygenation.

Human influence is the main driver of the observed trends in ocean warming, surface ocean acidification, the decrease in Arctic sea ice, and global mean sea level rise.

Ocean warming progressed faster over the past century than at any other time since the end of the last deglacial transition. Ocean acidification led to unusually low (i.e. increasingly acidic) surface open ocean pH levels in recent decades when compared to the last 2 million years. Both processes are projected to continue, as is ocean deoxygenation. Climate change might also affect entire ocean currents. The Atlantic Meridional Overturning Circulation (AMOC), for example, is predicted to weaken over the 21st century. While there is medium confidence that there will not be an abrupt collapse of the AMOC in this century, such a major tipping point of the climate system cannot be ruled out completely. The same holds true for other abrupt responses and tipping points, such as a strongly increased Antarctic Ice Sheet melt. The continued mass loss of both the Greenland and Antarctic Ice Sheets will contribute to global sea level rise over the 21st century. Even under large net negative CO2 emissions, it will take several centuries or even millennia for global mean sea level to reverse course. The Arctic Ocean will likely be practically ice-free during the seasonal ice minimum for the first time before 2050 under all scenarios, a state that might become the new normal by 2100 under continued high greenhouse gas emissions.

In discussion it was noted that COP25 was termed the 'blue COP' as there were many activities related to the ocean. COP26 in Glasgow resulted in a new declaration on the ocean and new members joined the 'blue leaders' aiming for 30% protection of the oceans by 2030. In the Glasgow Climate Pact there are also several references to the ocean, paving the path for more consistent inclusion and consideration of ocean issues in climate discussions. The US joined the high-level panel on oceans where members need to establish conservation management plans in their EEZ's that include many matters of interest to the IWC including shipping, tourism and climate change.

6. REVIEW OF LATEST DEVELOPMENTS IN TERMS OF UNDERSTANDING THE IMPLICATIONS OF CLIMATE CHANGE FOR CETACEANS

A list of recent publications had been produced for the workshop by Nunny and Frey and is annexed to this report (Annex D). This list was used to identify and subsequently invite workshop participants. Additional publications were added during the workshop.

The Chair noted that the matters under this topic would be discussed in the context of the presentations provided.

6.1 Major climate and non-climate drivers for impacts on cetaceans, including synergies

Smetacek and Savoca gave an overview on rebuilding baleen whale ecosystems and this is their authors' summary. They noted that the structure and functioning of marine pelagic ecosystems have been implicitly regarded as controlled by bottom-up factors. The same view was held by limnologists until whole-lake experiments demonstrated the effects of presence or absence of top predators: top-down control. Massive removal of top predators in the oceans by commercial fisheries was carried out without any management, hence its effects have not been appreciated. Whaling in the Southern Ocean (SO) provides a case study in which over a million great whales were removed but their recovery has been slow and is currently hampered by the decline of krill biomass.

To understand the impacts of top predators on ecosystem functioning the importance of iron availability in controlling productivity of the oceans needs to be considered. The bulk of this essential nutrient in productive ecosystems is located in the biota. The protein ferritin is highly effective at taking up and storing iron. Ferritin in body fluids renders these fluids as iron-limited as the open ocean. Phytoplankton blooms in today's SW Atlantic are almost entirely located along land margins that 'leak' iron to the impoverished water. Satellite imagery reveals that the spring diatom blooms are short-lived lasting only a month or two. Dedicated studies have demonstrated this is because biomass sinks to the sediments with its iron content. After the whales were removed the krill population shrank to a fraction of its former size over a period of several decades. The food required by baleen whales was initially estimated at 190 million tonnes of krill per year by Laws (1977); this has now been doubled by direct measurements of feeding rates of baleen whales in the field (Savoca *et al.*, 2021). The volume of krill consumed annually by whales is more than double the global fish catch. The size of the krill stock needed to satisfy large whale food demand will have been about 3 times the amount eaten: 1.2 Gt fresh biomass which is equivalent to 0.1 Gt carbon. This is in the same range of carbon in global livestock (0.1 Gt C) and human biomass (0.06 Gt C) (Bar-On *et al.*, 2018). The exceptionally high efficiency of conversion of plant production into animal biomass can only be explained by the biology of the animal actors involved in promoting transfer. They link the unique behavioural traits of krill and blue/fin whales into a pattern of recycling of the limiting element, iron, via bloom-forming diatom species in which the krill biomass acted as a gigantic reservoir of iron that was tapped and recycled by the whales which retained energy in the blubber. Since this function was eliminated with the removal of whales, the krill biomass sank to its current fraction of the original stock. The whale feeding grounds could be restored to their former glory by mimicking the whales as 'surrogate defecators' (Yong, 2021). The sole dependence of a dominant top predator on a single prey item contradicts the stability-by-diversity paradigm of ecology. The enormous krill biomass functioned as a reservoir of iron that was tapped and effectively recycled by the combination of unique properties of the whales and krill. In the past, whales generally fed on krill at the surface, thereby retaining iron released by krill faeces there. However, in today's Southern Ocean, krill appear to have retreated to greater depths where this fertilising mechanism is less effective. Rebuilding the baleen-whale ecosystem will require restoring the size of the krill iron reservoir by mimicking whale feeding and iron recycling. This could be achieved by artificial ocean iron fertilization (OIF) to grow diatom blooms that will provide food for krill reproduction. All OIF experiments carried out so far have stimulated growth of phytoplankton. After the first successful OIF experiments there was a concern that this could lead to large-scale fertilization for carbon sequestration by venture capitalists. To counteract this tangible threat, the London Convention has passed an international legally binding moratorium on large-scale OIF, until the results of smaller-scale scientific experiments show the degree of threat they pose. Applications for small-scale scientific experiments have to be peer-reviewed before permission is granted. Unfortunately, the unjustified negative reputation of OIF has discouraged scientists, funding agencies and policy makers from carrying out these badly needed experiments.

After this presentation by Smetacek and Savoca, the workshop discussed how krill seem to have occurred much more frequently at the surface in historical reports compared to its current deeper distribution. This will affect whale behaviour and their fertilising effect will be reduced at depth. The process described here is symptomatic of the entire ocean; the sub-Arctic Pacific Ocean is also iron deficient with likely the same effect on the whales of that region. This may be a possible reason that bowhead whale populations have not recovered as expected. There was debate about whether the system would be able to recover without intervention. Smetacek stated he did not believe krill populations can recover on their own and the iron reservoir needs to be built up. Whales are now feeding on krill exposed by receding sea ice and the nutrients are not going to be used by the phytoplankton.

The application of the new consumption estimates was questioned, noting that they were several times larger than earlier estimates and that further work is needed to explain the discrepancies.

6.2 Observed effects (cetaceans, habitats, prey and other species)

Stimmelmayr and Sheffield presented an integrated view on recent developments related to climate change in the Bering-Chukchi-Beaufort Sea. Long-term harvest monitoring and ongoing health assessments of landed Bering-Chukchi-Beaufort (BCB) bowhead have provided solid baseline data on population status and general health status, indicating a healthy and robust population in a general low stressor habitat. Ongoing risk surveillance of bowhead whale habitat and increased understanding about direct and indirect climate change impacts on the Pacific Arctic-subarctic marine ecosystem indicate an increasing complexity of environmental, ecological and anthropogenic stressors. For example, environmental and ecological changes are numerous, ranging from dynamic northward distribution shifts of Bering Sea Pacific cod and pollock; reduction in biomass of important forage fish (capelin, sand lance); extended residence time and further northward movement of subarctic baleen whales; changes in timing of bowhead whale spring and fall migration as well as novel overwintering in the Beaufort Sea; increasing killer whale- baleen whale predation; multi-year sea surface temperature variations from normal; continued decline in sea ice coverage; increasing presence of harmful marine algal toxins; ongoing unusual mortality events in gray whales, seals, and seabirds and more.

Since 2019/20 novel fishing for Pacific cod and pollock has successfully expanded northward in the Bering Strait and into the southern Chukchi Sea due to human impacts to ocean temperatures. Within the same time frame, maritime traffic along the Northern Sea route has significantly increased due to loss of sea ice and traffic is anticipated to become year-round by 2022. In 2020/21, several foreign marine debris events, likely associated with northern fishing and commerce vessel traffic, have occurred along the Alaskan coastline within the Bering Strait region. Lastly, recent microplastic (MP) monitoring studies in landed Eastern Beaufort Sea beluga whales and their prey confirm MP presence. Sea ice likely functions as a sink and with increased sea ice reduction more MP will enter the Pacific Arctic food web. Taken together, a real time status change of the Arctic-subarctic marine habitat is occurring from a low-level stressor exposure to a novel habitat potentially with concurrent high-level stressors. Given the current evolving dynamic landscape of known and emerging stressors within core areas of bowhead whale habitat, there is much urgency for federal co-management partners and coastal communities to engage in targeted research. Real-time Arctic stressor identification and impact characterisation is needed to develop actionable transboundary mitigation strategies. It was suggested that the accumulated ecological and biological knowledge about the bowhead whale can provide valuable, relevant, and transferable information to manage core large whale habitats in the Arctic-subarctic and devise realistic management strategies for a multi-user/multi-cetacean species Arctic seascape.

In discussion it was noted that the IWC Secretariat has reached out to local communities in the Arctic to propose a collaborative project to recover ghost fishing gear.

In terms of climate change, there is much progress needed to tackle this issue with swift and effective decisions. Scientists would need to recommend mitigation measures, even if for many situations the impact of these forces is still unknown.

In further discussion it was noted that the rapid changes occurring in the Arctic and other places in the world are concerning for people and for cetaceans, which is natural given human nature's aversion to change. The presentation by

Stimmelmayr and the earlier presentation by Striegel underscore the many reasons for concern given the changes being experienced. However, scientists should be cautious in assigning value to those changes. For example, there is evidence that sea ice retreat has been positive for bowheads because increased ice retreat likely increases productivity in the Beaufort Sea resulting in improved body condition (George *et al.*, 2015). Sue Moore and others have also suggested there are winners and losers in the array of impacts of climate change. Some species may be negatively impacted, and others may experience positive changes, although this may also change over time. There is an obvious need to continue to monitor cetaceans and impacts from climate changes where possible.

In the Arctic, there are often opportunities for scientists to work closely with subsistence hunters to collect samples from harvested whales on body condition, reproduction, and other aspects of health. Increased understanding of how climate change might be impacting cetaceans, could shed light on actions that can be taken to mitigate impacts from increasing human activities especially those that may be related to climate change (i.e. increased Arctic shipping, fishing, mining, etc.).

It was highlighted that the IWC manages aboriginal subsistence harvests of baleen whales in the Arctic using Strike Limit Algorithms (SLAs), which were rigorously tested across a broad range of scenarios. Some of the stressors referenced by Stimmelmayr and Shefield are covered by those scenarios. Givens and Weller (2021) determined that some of those changes were well within tested parameter space and that the SLAs for BCB bowheads and gray whales were still the appropriate tool for the SC to provide advice to the Commission about the sustainability of aboriginal hunts.

It was emphasized that there will be some negative and positive effects from climate change, and the situation in the Arctic is complicated, as it is clear that increased human activity will definitely have an effect. Easy wins can be identified and implemented as a priority, where negative effects can be mitigated, especially those that will take a long time to reverse. Tulloch has started a meta-analysis on teasing out some of the differences between the northern and southern hemisphere in relation to the positive and negative effects and how they interplay.

Williams presented new information from a population viability analysis (PVA) for beluga (*Delphinapterus leucas*) that explicitly included climate change (Williams *et al.*, 2021). Decades after a ban on hunting, and despite focused management interventions, the endangered St Lawrence Estuary (SLE) beluga population has failed to recover. The authors conducted a population viability analysis (PVA) to simulate responses of the SLE beluga population across a wide range of variability and uncertainty under current and projected changes in environmental and climate-mediated conditions. Three proximate, anthropogenic threats to recovery were explored: ocean noise, which may reduce foraging efficiency; contaminants, which can increase calf mortality; and prey limitation, which can affect both survival and reproduction. Even the most optimistic scenarios the authors modelled failed to achieve the reliable positive population growth needed to meet Canada's stated recovery targets. Every climate change scenario that the authors considered exacerbated the immediate threats and further reduced population growth. The study found that the predicted effects of climate change may be a more significant driver of SLE beluga population dynamics than all three proximate threats considered. The authors concluded that aggressive mitigation of all three proximate threats will be needed to build the population's resilience and allow the population to persist long enough for global actions to mitigate climate change to take effect.

The PVA approach was thought to be useful in teasing out scenarios and this could be used for prey availability e.g. looking at climate change effects on herring. The inclusion of seasonal information into the approach would also be beneficial.

The workshop made the following recommendation on recovery efforts for endangered species.

Attn: CG, C, G, R
The workshop welcomed the information on St Lawrence Estuary beluga. The workshop encouraged countries to follow the good example set by Canada and consider climate change explicitly in recovery efforts for endangered species. The workshop ***recommended*** *that doing so will require swifter, more effective and targeted mitigation to reduce or remove anthropogenic stressors (e.g., prey limitation, ocean noise, bycatch, toxins). Additional protective measures (e.g., critical habitat designation, marine protected areas) may be required to help build the resilience of cetacean populations to withstand climate-mediated stressors.*

Carlén reported on climate change effects on the four species of marine mammals present in the Baltic; ringed seal (*Pusa hispida baltica*), grey seal (*Halichoerus grypus*), harbour seal (*Phoca vitulina*) and the critically endangered Baltic Proper harbour porpoise (*Phocoena phocoena*). The Baltic Sea is being highly affected by climate change. For example, sea surface temperatures (SST) have increased more in the Baltic than in many other areas. This influences the length of the ice season and maximum extent of sea ice, which has a negative effect on the reproductive success of the ice breeding ringed seal. Increased inflow of freshwater due to increased precipitation in the north in combination with increased influx of salt water from the southwest and warming of surface waters is expected to increase stratification which is already strong in the Baltic Sea. This in turn may aggravate the already serious oxygen depletion primarily in deep areas but also in some coastal areas of the Baltic. Oxygen depletion and ocean warming is likely to have a negative effect on pelagic saltwater fish species such as cod (*Gadus morhua*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*), which are thought to be important prey for Baltic harbour porpoises. Meanwhile, smaller species such as three-spined stickleback (*Gasterosteus aculeatus*) are expected to benefit from warming. This may reinforce the ecosystem changes already observed and decrease harbour porpoise prey quantity and quality. Effects in the Baltic were recently reviewed in Meier *et al.* (2021).

The Baltic Proper harbour porpoise is critically endangered. The population is small (Amundin *et al.*, 2021) with a limited population range (Carlén *et al.*, 2018), and cumulative impacts from bycatch, environmental contaminants and underwater noise are already hindering population recovery (Carlén *et al.*, 2021). Additional pressure from climate change is likely to further aggravate the situation for this population. The IWC Scientific Committee in 2021 made recommendations related to action to help address the situation of the Baltic Proper harbour porpoise[2].

The workshop noted that the Baltic situation highlighted the need to account for cumulative effects as there is a whole suite of threats and problems that cannot be addressed in isolation, and therefore made the following recommendation.

Attn: CG, G
The workshop noted with concern the situation of the critically endangered porpoise of the Baltic proper, and the comments made previously about it by the scientific committee, and that climate change would likely exacerbate its demise. The workshop, therefore, called on its range states to urgently act to improve the resilience of this population by addressing the other imminent threats affecting it, including bycatch.

6.3 Lessons from other species

Staniland presented on the lessons learnt from the study of climate effects in other marine predators. Large and relatively conspicuous top predators, including cetaceans, are often used as 'Ocean Sentinels' sitting at, or near the top, of the food chain. As such, they integrate changes in the marine ecosystem and provide a range of different measures that can be used to provide a window into the cryptic marine environment. From simple counts on breeding sites to using animal-borne technology to measure individual dives, whole range of life history parameters and behaviours can be monitored, covering time periods of seconds to decades and beyond. Compared to cetaceans, other marine large predators such as seabirds, seals and turtles are often easier and cheaper to monitor as they haul out on land or ice to breed, rest or moult, etc. They can be proxies for what is, or may be, affecting cetacean populations as they often share the same habitats and overlap in diet. However, care is needed given the different life history constraints acting on these animals such as their need for access to land etc.

Examples include elephant seals (*Mirounga sp.*) carrying Conductivity-Temperature-Depth (CTD) tags which become oceanographic samplers, targeting areas of interest and giving an understanding of the preyscape through body condition changes (Costa *et al.*, 2010). The use of krill (*Euphausia superba*) carapaces in Antarctic fur seal (*Arctocephalus gazella*) scats was highlighted as a simple long-term study by which the recruitment of krill at South Georgia had been monitored. Dietary sampling has also been used to predict the future with the amount of sardines (*Sardinops sagax*) and anchovy (*Engraulis mordax*) correlated to fisheries catch per unit effort (CPUE) and landings in the following year (Velarde *et al.*, 2015). Range shifts have been observed in both Northern and Southern elephant seals, although interestingly the underlying mechanisms are probably different with hyperthermia affecting NH seals (García-Aguilar *et al.*, 2018) and ecosystem changes affecting the SH (Jones *et al.*, 2020). These range shifts are also observed in seals on the western Antarctic peninsula with less ice-dependent species increasing and the ice obligate Weddell seals (*Leptonychotes weddellii*) decreasing (Hückstädt *et al.*, 2020). In the Bering Sea, ribbon seals (*Histriophoca fasciata*) showed a long-term decrease in their body condition in contrast to adult spotted seals (*Phoca largha*). This appears to be related to decreasing sea ice extent which results in a separation between breeding and deep water foraging sites for ribbon seals but not for spotted seals which favour shelf waters (Boveng *et al.*, 2020).

The issue of nonlinear responses to environmental changes was highlighted in South American sea lions (*Otaria flavescens*), where wave power exceeding a threshold value significantly increased the number of pups washed away by storms (Sepúlveda *et al.*, 2020).

Seabirds are a group that are relatively well studied, and a global analysis of breeding success showed hemispheric differences (Sydeman *et al.*, 2021). The Northern Hemisphere, with greater industrial exploitation and warming, showed the strongest effects in fish-eating, surface-foraging species. In the final example, divorce in black-browed albatross (*Thalassarche melanophris*) was shown to increase with SST even accounting for the effects of chick failure (Ventura *et al.*, 2021). This has implications for the lifetime reproductive output of these birds and could be linked to delayed return to breeding sites or increased stress hormones. Staniland noted that all of the examples relied on long term monitoring and the importance of both maintaining these and establishing new programmes was emphasised.

The use of new and emerging technologies was also noted to be potentially of great help in long term monitoring, reducing costs or expanding what can be monitored, and the workshop made the following recommendation.

[2]*https://archive.iwc.int/?r=19277.*

Attn: R, CG, G
The workshop noted that long term monitoring programmes were essential to detect climate driven changes in both cetacean populations and their habitats. The workshop therefore:

(1) *urged funding bodies, other government agencies and relevant bodies to support existing long term monitoring programmes and encouraged the development of new programmes; and*
(2) *encouraged the use of new and emerging technologies to reduce the cost of these long term monitoring programmes and open up new areas of research.*

6.4 Case studies

6.4.1 North Atlantic right whales

Corkeron presented information on North Atlantic right whales *Eubalaena glacialis*, (NARW) and climate change: what lessons can we learn? North Atlantic right whales are an exemplar of the challenges facing large whale conservation in the face of climate disruption. Their slow, intermittent recovery from centuries of commercial whaling stuttered to a halt in 2010, when the species' abundance peaked at a little under 500 individuals (Pace *et al.*, 2017). NARW numbers have declined since then, to around 336. The primary causes of the decline are twofold: anthropogenic mortality, from entanglement in fishing gear and vessel strikes; and poor reproductive output, for reasons that remain less well established but include the effects of entanglement, and changes in the distribution and abundance of the whales' prey, *Calanus finmarchicus*. Record *et al.* (2019) and Meyer-Gutbrod *et al.* (2021) clearly outline the manner in which climate disruption has had a significant role in this disaster.

Work on NARW demonstrates how many of the projected concerns raised in other presentations at this workshop play out in real life once whales are impacted by climate disruption. Anthropogenic perturbation of the ocean is ubiquitous, so wherever whales move to, they will encounter new anthropogenic threats. In the case of NARW, it has taken too much time to: (1) recognize that their movement ecology has been altered; (2) locate their new habitats; (3) assess the manner in which these habitats are subject to anthropogenic perturbation; (4) identify key threatening process; and (5) take management action in a manner that is appropriate and effective in addressing these threats. Current scientific and management processes are demonstrably inadequate (NARW are still declining in abundance) to address their climate-driven changes in movement and foraging ecology. A new paradigm, that moves beyond the post-hoc approach of attempting to understand a problem long after it has occurred, is required for those cetacean species that occur at low abundance, and arguably, for all. NARW demonstrate that management for resilience, rather than management for immediate sustainability, is the required paradigm shift.

The workshop noted that the issue of the NARW showed that there was a need to respond to situations in a rapid dynamic way. There was a need to move away from thinking that the ocean was 'the wild' and animals could simply move from one industrialised area to another. Animals may also be more vulnerable than before when moving to a new area. The workshop therefore made the following statement.

Attn: GC, G
The workshop noted with concern that aspects of the movement, ecology and life history of the Critically Endangered North Atlantic Right whale have changed in response to ecosystem perturbations brought on by climate disruption. This means that more anthropogenic stressors are now impacting this species, which is in significant decline. The workshop therefore called for the relevant authorities to react more quickly and more effectively to reduce anthropogenic impacts in response to these changes.

6.4.2 Sea ice and the eastern North Pacific (ENP) gray whale

Joyce provided new information on the role that sea ice plays in the distribution, phenology, and population biology of eastern North Pacific (ENP) gray whales (*Eschrichtius robustus*), with a view towards trying to understand the mechanisms by which ongoing climate change may affect this population. Highly variable annual estimates of ENP gray whale calf production have shown a negative correlation (ρ = -0.6) with Pacific Arctic Sea ice cover over recent decades (Perryman *et al.*, 2020). This has prompted a hypothesis that extensive late-spring/early-summer ice may physically exclude reproductive females from early season access to important benthic foraging hotspot habitats during an energetically demanding phase of gestation associated with a return from long distance migration and accelerated foetal growth. Researchers examined whether patterns of gray whale distribution and phenology in the Pacific Arctic aligned with this proposed mechanism, particularly in light of two recent deviations (2013-14 and 2017-19) from historical patterns of negative correlation between reproductive output and ice cover. Overall, a nonlinear negative relationship was found between gray whale aerial counts and sea ice cover (GAM, $p<0.001$), with an increase in negative slope above 45-55% sea ice concentration. Extensive aerial survey effort (641,461km) recorded a small number of gray whale observations at local sea ice concentration values up to 90-95%. However, these rare sightings at high sea ice concentrations generally occurred along the periphery of larger masses of sea ice and no gray whales were sighted >7km inside the 40% sea ice concentration contour. Comparisons of early season distribution patterns further revealed that gray whale sightings were absent in several key foraging hotspot habitats during years with delayed ice break-up but were present in these habitats in years of early-to-average ice retreat. Passive acoustic records of gray whale vocalizations were somewhat difficult to interpret, however the totality of evidence from aerial and acoustic gray whale observations in the Pacific Arctic was consistent with the hypothesized sea ice exclusion mechanism. These results provided additional lines of evidence supporting an important role of sea ice in gray whale habitat use and reproductive success with implications for population dynamics in a rapidly changing Arctic environment.

The influence of sea ice cover on algal blooms and the knock-on effects to prey availability was discussed as one of the research areas being addressed. Changes in the macro fauna and the dramatic habitat shift were being studied and there may be some switching to pelagic prey, again highlighting the factors where climate change is potential having an effect.

6.4.3 River dolphins

Fernando Trujillo, on behalf of himself, E. Aliaga, Y. Briceño and M. Frias, presented on the issue of climate change and river dolphins in the Amazon and Orinoco basins.

River dolphins in South America are distributed in three river basins: the Amazon, Orinoquia and Tocantins/Araguia, an area of more than 9 million square kilometers. The transformation of these watersheds is enormous due to multiple human activities that threaten not only the dolphins, but also the ecological integrity of these aquatic ecosystems. Climatic alterations, including temperature increases, changes in flood pulse patterns and water stress, constitute a major emerging threat to river dolphin conservation. This has been particularly evident in the Orinoco region of Colombia and Venezuela and in the Bolivian Amazon.

During the last ten years, an increased frequency of dolphins that become trapped in river segments and must be rescued and translocated to areas where their survival is guaranteed has been reported. In the Colombian Orinoquia there were at least 23 individuals and, in the area of the Rio Grande in Bolivia, at least 58. These events are the result of the combination of water stress with deforestation and industrial extraction of water for agricultural crops. The main threat of water stress to dolphins is the effective loss of habitat, considerable reduction of their prey and the possibility of being trapped in bodies of water that eventually dry up and where they would die from starvation, burns and thermal shock.

Future scenarios are not promising, as threats continue to increase. Climate models predict that by 2050 the Amazon could experience a temperature increase of 2 to 3° Celsius and a reduction in vegetation cover of between 30 and 60%, changing from tropical rainforest to savannah ecosystems. Reduced rainfall in the dolphins' range may drastically reduce nutrients in rivers, and flood pulses are already being affected in their periodicity and duration. High temperatures produce anoxic conditions in the water and changes in pH that can be lethal to fish and all life in the water. Dolphin stranding events are increasing every year and there is insufficient logistical and economic response capacity to deal with them. It is necessary to create an emergency fund, train teams in different regions and establish adequate translocation protocols.

In light of the climate-related threats to river dolphins, the workshop made the following recommendation.

Attn: CG, G, R

In light of the climate related threats to river dolphins the workshop **recommended** *the:*

(1) *development of translocation protocols, for dolphins marooned in unsuitable habitats, that include appropriate training, habitat analysis and funding;*
(2) *incorporation of hydrological monitoring into the CMP of South American river dolphins;*
(3) *creation of a network of appropriate experts to assist in river dolphin conservation and management incorporating scientists from different disciplines, representatives from local communities, and Government authorities;*
(4) *implementation of forest restoration programmes where dolphins might be affected; and*
(5) *enhancement of regulations in aquatic habitat conservation in Protected Areas and Ramsar sites.*

6.4.4 Movement of whale species

Tore Haug reported on a review of baleen whale ecology in high-latitude marine ecosystems of both the north Atlantic and north Pacific (Moore *et al.*, 2019).

Biophysical changes in marine ecosystems of the Arctic and subarctic sectors of the Atlantic and Pacific are now evident, driven primarily by sea ice loss, ocean warming and increases in primary productivity. As upper trophic species, baleen whales can serve as sentinels of ecosystem reorganization in response to these biophysical alterations, via changes in their ecology and physiological condition. Oceanographically the north Atlantic and north Pacific offer four contrasting habitats to baleen whales: (i) a broad-deep-strait and deep-shelf inflow system in the Northeast Atlantic (NEA); (ii) a combination of inflow and outflow systems north of Iceland in the central North Atlantic (CNA); (iii) an outflow shelf and basin in the Northwest Atlantic (NWA); and (iv) a narrow-shallow-strait inflow shelf system in the Pacific sector. Information on baleen whale ecology from visual and passive acoustic surveys, combined with available telemetry and diet studies, reveals contrasting patterns of baleen whale occurrence among sectors. In brief, arctic and subarctic waters in the Atlantic sector support a far greater number of seasonally migrant baleen whales than the Pacific sector. Thousands of humpback, fin and common minke whales occupy the diverse habitats of the Atlantic sector. These species all exhibit flexible diets, focused primarily on euphausiids (krill) and forage fishes (e.g. capelin, herring, sand lance), which are now responding to ecosystems altered by climate change. Conversely, the Pacific sector supports a far greater number of arctic-endemic bowhead whales than the Atlantic sector, as well as a large population of seasonally migrant gray whales. Currently, differences in migratory timing and, to a lesser extent, foraging behaviours, serve to restrict prey competition between the arctic-endemic bowhead whale and seasonally migrant baleen whale species in both sectors. Regional aspects of changes in prey type and availability will likely impact future migratory timing, habitat selection, body condition and diet of baleen whales. Tracking variability in these attributes can provide valuable input to ecosystem models and thereby contribute the sentinel capability of baleen whales to forecasts of future states of high latitude marine ecosystems.

In discussion it was noted that in Icelandic and adjacent waters in the Central North Atlantic, substantial changes in the ecosystem have been reported during the last 2-3 decades concomitantly with increases in temperature and salinity (Astthórsson *et al.*, 2007; Jónsson and Valdimarsson, 2012; Tsubouchi *et al.*, 2021). These changes include pronounced changes in distribution and abundance of several fish species (Campana *et al.*, 2020; Carscadden *et al.*, 2013; Jansen *et al.*, 2020; Valdimarsson *et al.*, 2012) some of which are important forage fish for cetaceans (e.g. capelin and sandeel). During this period (1987-2015) appreciable changes have been observed in distribution and abundance of several cetacean species in Icelandic and adjacent waters (Víkingsson *et al.*, 2015). Fin whale distribution has expanded into the deep waters of the Irminger Sea and their overall abundance has increased. On the Icelandic continental shelf area, humpback whale densities have increased while common minke whale abundance decreased abruptly between 2001 and 2007 (Pike *et al.*, 2020). In terms of biomass, humpbacks have replaced common minke whales as the dominant cetacean species in the Icelandic shelf area (Víkingsson *et al.*, 2015). A research project on the diet of Icelandic minke whales during 2003-07 revealed substantial changes in diet composition, that appeared to be related to changes in prey abundance including a near-collapse of the sandeel population (Víkingsson *et al.*, 2014; 2015). According to the Norwegian NILS surveys (Solvang *et al.*, 2017), the abundance of common minke whales in the Jan Mayen area (also part of the Central North Atlantic medium management area) were considerably higher than in any of the previous surveys in that area. Thus, the data from surveys and diet studies suggest that minke whales in Icelandic waters have responded to recent changes in the environment by a northward shift in distribution and change in diet.

The workshop noted there might be complications in surveying whales due to populations shifting their ranges given climate change, as underscored in this study, and the need to consider whether the tools currently used are still fit for purpose. The timing of surveys may also need to change in line with migration patterns. Long-term surveys are typically consistent in their timing and the area covered, an issue that must be considered in conducting abundance surveys.

6.4.5 Out of habitat animals

Nunny presented on belugas (*Delphinapterus leucas*) which have been recorded potentially outside of what is regarded as their normal habitat or range. This is part of an ongoing project by OceanCare on marine mammals which appear in areas away from their natural habitat and in locations where their health and welfare may be threatened because they come into close contact with human activities or find themselves in unsuitable habitat. Nunny showed a map with 61 records of belugas in Canada, USA, Europe, Japan and Russia. Many of them were recorded in the last 20 years and suggested that it is worth considering whether climate change is prompting these animals to stray from their normal range. It was noted in discussion that other polar species are also being recorded far from what is thought to be their normal distributions, including two walruses in Europe this summer. An international workshop was recently held on these 'out of habitat' animals and how they might best be responded to under the auspices of the UK's Marine Animal Rescue Coalition (Anon., 2021).

It was also noted in discussion that some of the animals highlighted may be exhibiting a natural dispersal phase and that more work needed to be done to establish normal ranges and behaviours. This project is ongoing and this will be further considered.

6.5 Detecting effects

6.5.1 Population assessment

Bengston Nash gave a presentation on Southern hemisphere humpback whales (*Megaptera novaeangliae*) that were recently implemented as sentinels of the Antarctic sea ice system through a Southern Ocean Observing System (SOOS) endorsed project and UN Ocean Decade endorsed activity. Their dependence on southern hemisphere populations on sympagic (ice associated) Antarctic krill (*Euphausia superba*), and their extreme energetic adaptations and migratory life history render them highly suited to this ecosystem surveillance approach. To date, humpback whale populations migrating to Brazilian (A), western (D) and eastern (E1) Australian, and New Caledonian (E2), and Colombian (G) breeding grounds have been included into the Humpback Whale Sentinel Program (HWSP) for circumpolar surveillance of the Antarctic sea ice ecosystem. The longest record of annual measurements (14 years) is available for the E1 migrating stock. The Program targets the sentinel parameters of Adiposity, diet, and fecundity via a toolbox of eight traditional and novel ecological tracer techniques applied to biopsied tissues from healthy free-roaming animals. To date, the E1 timeline has captured two extreme climatic events in Antarctica: the extreme La Niña event of 2010/11, and most recently, the anomalous climatic events of 2017. In these years whales migrated in poorer body condition, fewer females participated in the migration, and higher calf mortalities were recorded. The role of Antarctic sea ice in influencing krill abundance and availability to predators remains an active area of research, and one which carries clear consequences for the Southern Ocean baleen whale populations. Similarly, the HWSP presents a useful platform for investigating the ecophysiological response of a large cetacean to multiple stressors.

The workshop noted that this work related to several agenda items and posed the question of whether cetaceans make good indicators of climate change. The methodology used in the study was roundly praised and the difficulty in funding such projects was highlighted. A great deal of emphasis is put on novel research but the importance of longer timelines giving power to the analyses was again acknowledged. Piggybacking on other projects, developing new techniques, using existing platforms and collaborating widely were all ways of overcoming difficulties in maintaining these programmes.

The importance of understanding the monitored subjects' ecology was emphasized and a lot of effort had been spent in validating the assumptions such as whether the whales migrate every year. Another example was the use of fatty acid signatures needing careful interpretation as the whale's prey, krill, is omnivorous and this may be a way of looking at the source of the primary productivity. The study was also seen as a framework with which to study non-migratory species such as the Arabian Sea humpback whale. It was noted that tissue samples, if stored correctly could be used to look retrospectively at the animals' health at the time of sampling and only 100mg is needed.

The use of drones to collect data on body condition was an example of the use of new technology being incredibly useful and cost effect.

7. THE IWC ECOSYSTEMS FUNCTIONING WORKSHOP

Ritter reported on an Ecosystems Functioning (EF) workshop held in response to IWC Resolution 2016-3 (IWC, 2017) which 'recognized the need to include consideration of the contributions made by live cetaceans and carcasses present in the ocean to marine ecosystem functioning in conservation, management strategies and decision making.' The Resolution asked the IWC Scientific Committee to develop a gap analysis in regard to research and to develop a plan to prioritize research needs.

The Ecosystems Functioning workshop reviewed existing knowledge on the contribution of cetaceans to ecosystem functioning and addressed four topics: whale falls; nutrient circulation and ocean fertilization and cetaceans as predators (IWC, 2022)[3].

The EF workshop agreed that often it is not a question of whether whales play a role in ecosystem functioning but rather what role they play, which is largely dependent on the scale (from local to global). Given the differences amongst cetacean species it is important not to generalize ecological functions and variations in temporal and spatial scale. It was also noted that a variety of marine species, including small cetaceans, other marine mammals, sharks, large fish, and seabirds also contribute to nutrient availability and transport to marine and terrestrial ecosystems providing important ecological benefits including increasing primary production.

The impact of population declines from commercial whaling on ecosystem functioning was highlighted including the significant loss in carbon sequestration value as a result of commercial whaling. The impact of climate change and other anthropogenic threats on cetaceans and the ecosystem functions they provide was also discussed. It was agreed that studying human-induced changes, including climate change, and their impact on cetaceans' ecosystem functioning is important. Interest in the issue of ecosystem functioning of cetaceans, particularly in the context of climate change, has gained momentum internationally and will likely increase. Discussions about 'blue carbon' and nature-based solutions (NBS) are of interest to stakeholders, especially ENGOs and decision-makers.

In discussion all agreed that given the overlap of the Scientific and Conservation Committee groups it was important for them to work together. Given that climate change is ubiquitous, addressed across all groups, a discussion was needed about the best way to address this issue as it was felt it was not being picked up properly at the moment. Possible ways to do this was to form a working group or have it as an agenda item in more than one sub-group but it would be good learn from other similar organisations as to how they manage this issue. Several other issues span the work of the Scientific Committee, and a consolidated approach would be useful.

8. CAN CETACEANS BE USED AS INDICATORS OF CLIMATE CHANGE?

8.1 Which species, where/what and indicator for what?

See discussion and presentations in Item 6.

[3]*https://archive.iwc.int/?r=19252.*

8.3 Linking to appropriate political processes

See Item 10.

8.4 Identifying and collaborating with relevant climate processes and initiatives

Holm presented an overview of the workshop on Pollution 2025, an initiative of the Scientific Committee's sub-committee on Environmental Concerns. The aim was to study how cumulative impacts from exposure to multiple stressors could best be investigated, which new methods and techniques could be helpful, and which mitigation measures might be recommended. To this end, several frameworks and models were discussed, as well as the utility of tissue culture techniques, aerial and drone photogrammetry, -omics biomarkers, adipocyte index, epigenetics and novel in silico and in vitro techniques. Case studies were presented, such as on the *Deepwater Horizon* oil spill, on health assessments of bowhead whales, a Spanish project on stressors involving trophic interactions, and a monitoring project of harbour porpoises in the Baltic Sea. The participants agreed on the need to understand the biological processes on all levels of the organisms up to the population level. Baseline data, e.g. on adult survival rates, and health measures should be raised more systematically to facilitate comparisons amongst vulnerable populations and develop effective measures. There is a need for long term monitoring studies and the identification of potential indicator species and sentinel parameters. Monitoring of vulnerable populations before stressors occur should be promoted. Recommendations are under development but, in general, the reduction of the amount and level of stressors should be pursued. More interdisciplinary research is recommended and establishing or strengthening the science-policy interface to consider multiple sources of morbidity when developing conservation and management measures.

The Chair thanked Holm and congratulated her on a well-run workshop.

9. RESPONDING TO THE CLIMATE CHANGE THREAT THROUGH 'CLIMATE SMART' MANAGEMENT OR SIMILAR APPROACHES

9.1 Direct response to address and reduce causes of Climate Change - including how to make whale assessments carbon neutral

This matter was not discussed at the workshop but may be considered at a future meeting of the IWC Scientific Committee.

9.2 Adaptive management 1: Potential management actions in response to climate driven changes that may make cetaceans more vulnerable to anthropogenic threats (e.g. changes in distribution in relation to shipping and fisheries, impacts on health)

The workshop considered how changes in human activities as a result of climate change may impact cetaceans. Shipping presents a number of threats, in particular ship strikes and underwater noise, which have been being considered by the Scientific Committee for many years.

In 2018, the International Maritime Organization (IMO) adopted an initial strategy to reduce the total annual GHG emission by at least 50% by 2050 compared to 2008. In November 2021, the IMO recognised the need to strengthen the ambition of this initial strategy and agreed to revise its GHG strategy by 2023. However, it was not able to agree on the level of ambition or set specific new targets. Reducing speeds across shipping fleets has been shown to make a substantial contribution to reducing greenhouse gas (GHG) emissions and remains an effective short-term measure that could be implemented straight away.

Leaper presented an analysis of how reduced ship speeds would also reduce underwater noise and ship strike risk. A number of different speed reduction scenarios that would contribute to GHG reductions were examined. A modest 10% speed reduction across the global fleet has been estimated to reduce overall GHG emissions by around 13% (Faber *et al.*, 2012) and improve the probability of meeting the initial IMO GHG targets by 23% (Comer *et al.*, 2018). Leaper (2019) concluded that such a 10% speed reduction, could reduce the total sound energy from shipping by around 40%. The associated reduction in overall ship strike risk is more uncertain but could be around 50%. Thus, implementing speed reductions would have multiple environmental benefits. It would benefit whale populations globally and complement current efforts to reduce collision risk in identified high risk areas through small changes in routing.

A study commissioned by Belgium had also examined the expected changes in underwater noise in the North Sea based on limiting the speed of all ships to 75% of their design speed. This showed a significant reduction of the emission of greenhouse gasses (of about 10%) combined with a reduction of the underwater noise of 1 to 4 dB (de Jong *et al.*, 2020).

9.3 Adaptive management 2: Responses to expected and observed changes in human activities as a result of climate-driven changes (e.g. increased shipping in Arctic, changes in fisheries, storm-related sewage discharges) and potential management actions in anticipation of these changes

This issue was in part covered under agenda but may be considered at a future meeting of the IWC Scientific Committee.

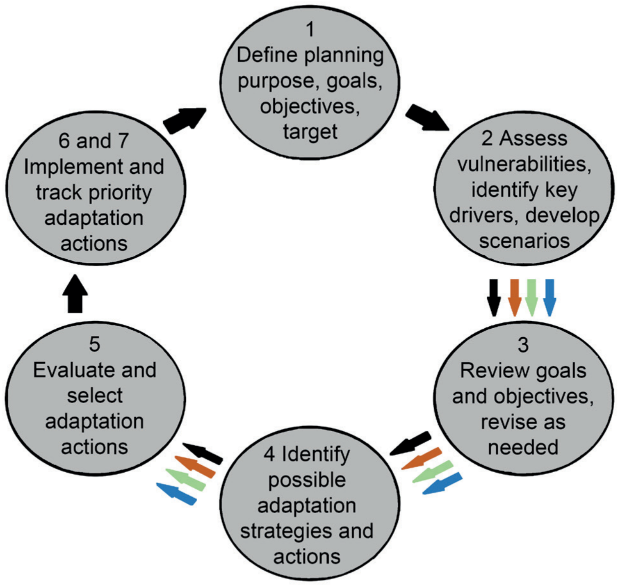

Fig. 1. A slightly modified version of the Climate-Smart Conservation Cycle (adapted from Stein *et al.* (2014) showing where scenario planning can be incorporated to help address uncertainty.

9.4 Adaptation Toolbox: Management to enhance the adaptability and resilience of cetacean species

9.4.1 Climate Smart Conservation Cycle

Dick presented on this issue. Rapidly changing ecosystems are raising questions such as: How can we prepare for and respond to the impacts of climate change on wildlife and their habitats? What should we be doing differently given these climatic shifts and what actions make sense to continue? The field of Climate Change Adaptation evolved to address these questions and is founded on the concept of climate-smart conservation, defined by Stein *et al.* (2014) as 'the intentional and deliberate consideration of climate change in natural resource management, realized through adopting forward-looking goals and explicitly linking strategies to key climate impacts and vulnerabilities'. The goal of her presentation was to provide a brief overview of several climate adaptation tools and how their use can help address climate change impacts on species and ecosystems and lead to more climate-informed management and science actions.

There are four overarching themes behind climate-smart conservation: (1) act with intentionality; (2) manage for change, not just persistence; (3) reconsider goals, not just strategies; and (4) integrate adaptation into existing work. Ensuring that conservation planning addresses each of these themes can better prepare for managing resources in ways that account for surprises by adopting strategies that are robust to uncertainty.

Tools noted in the presentation were as follows.

(1) The Climate-Smart Conservation Cycle is a framework developed to help with the design and implementation of conservation and resource management issues in the face of climate change. The seven-step cycle, outlined in Fig. 1, is modified slightly to incorporate the scenario planning process. Although this cycle shows a one-way process, it is more of an iterative process, providing opportunities to reflect on previous steps and updating/adjusting as needed.

(2) Climate Vulnerability Assessments (CVAs) are based on the extent to which a species, habitat, ecosystem, place, or project is susceptible to impacts of climate change. CVAs can indicate what is more or less vulnerable and why. This information can contribute to setting priorities or adaptation and conservation actions whilst not specifying the management or policy decisions.

(3) Scenario Planning is a structured process that embraces uncertainty and uncontrollable conditions to explore plausible alternative future conditions under different assumptions to help manage risk and prioritize actions. This process lends itself well to exploring the uncertainty surrounding changing environmental conditions, and it is widely applicable to natural resource management issues. Scenario planning takes what is known today with any number of uncertainties to yield a number of relevant futures for which to prepare. Scenarios allow questions to be raised such as what risks and opportunities will be faced with each scenario? What should be done now to prepare for each scenario? How should any of these scenarios be tracked as they play out over time? This tool can be used to inform recovery planning, resource management in MPAs, and rapid response planning for oil spills, extreme weather events or other disasters.

(4) Resist - Accept - Direct Framework is a tool developed to help make informed, purposeful, and strategic choices to conserve species and ecosystems undergoing ecological transformation. Generally speaking, one can respond to a changing world by resisting - where you work to maintain or restore based upon historical or acceptable current ecosystem conditions, accepting - allowing an ecosystem to change without intervening, or directing - where you actively shape ecosystem change toward preferred new conditions.

(5) MPAs are a source of Blue Carbon through the biodiversity they contain, including the contributions made by the presence of marine mammals within MPAs. These combined benefits were recognized at COP26 with the formal establishment of the International Partnership on MPAs, Biodiversity and Climate Change[4] - an alliance of international government agencies and organizations, working together to progress the evidence base around the role of Marine Protected Areas (MPAs) and biodiversity in tackling climate change. This idea is being explored further by the Greater Farallones National Marine Sanctuary in their two-part series focused on increasing the protection of blue carbon through the use of MPAs[5].

9.4.2 Climate-informed goals and objectives
This matter was not fully discussed at the workshop (but see step 3 in the Climate-Smart Conservation Cycle discussed above) and could be more fully considered at a future meeting of the IWC Scientific Committee.

9.4.3 Vulnerability Assessments (examples: NOAA and ECOADAPT)
Lettrich gave an overview of the use of climate vulnerability assessments (CVAs) for NOAA. Marine mammal management and conservation rely on the best available information. CVAs provide a coarse step to improve understanding of climate change impacts on marine mammal populations. CVAs are a tool used to determine which populations are most vulnerable to a threat, in this case climate change, and what makes them vulnerable. The typical structure of a CVA is that it has three components: (1) exposure; (2) sensitivity; and (3) adaptive capacity (Intergovernmental Panel on Climate Change (IPCC), 2007). A number of vulnerability assessment frameworks exist for a variety of purposes (e.g. wildlife, built systems, social systems; Intergovernmental Panel on Climate Change (IPCC) (2014); Foden *et al.* (2019). Although more vulnerability assessments have been conducted for terrestrial species and habitats than for those in the marine environment, marine species have received recent attention and CVAs, or elements thereof, have been conducted for marine mammals with differing scopes and scales (Albouy *et al.*, 2020; Laidre *et al.*, 2008; Sousa *et al.*, 2021). NOAA Fisheries developed a trait-based CVA approach that uses expert elicitation to score an exposure module and a combined sensitivity/adaptive capacity module for each population and those scores are used to calculate a vulnerability score (Lettrich *et al.*, 2019). Exposure is scored by estimating projected change in environmental parameters within the population's range. Sensitivity and adaptive capacity are scored by estimating a population's biological and ecological traits within a defined scoring rubric (see Lettrich *et al.* (2019) for the full method description and Sousa *et al.* (2021) for use of the method in Macaronesia). Results from the CVAs are expected to be used to guide management actions, contribute to management plans, and help identify research questions. As these approaches are used in more regions, a comparison of methods and results would improve results interpretation and translation to management.

The workshop discussed the disconnect between the global distribution of a species and what can be done about it locally. NOAA scientists are looking at stocks, taking it to a level that management can act upon, looking at exposure to a threat rather than looking over entire large-scale regions. The potential problem with 'group think' was raised as the majority opinion or the loudest voices could sway others or bias results. In response, it was noted that the techniques used have been developed over decades. The criteria are well defined and, in this study, individuals first score independently before group discussions and then independently again, all to minimise undue bias. The IPCC and the Integrating Climate and Ecosystem Dynamics programme (ICED) have used these approaches, but expert consensus is always difficult to achieve.

Work with the North Atlantic right whale has had a strong local focus, with known threats when they are in US waters. NOAA has gone to the effort to assess the threats on the scale that they live their lives even if this means transboundary cooperation otherwise models may only be capturing a small percentage of the problem. It was highlighted that scientists/researchers should quantify the known as well as the unknown.

10. RECOMMENDATIONS FOR FURTHER RESEARCH AND IMPROVING POLICY, INCLUDING RECOMMENDATIONS TO OTHER IGOS AND BUILDING LIAISON, INCLUDING IUCN AND IMMAS

10.1 IMMAs
Important Marine Mammal Areas (IMMAs) are defined as discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation. They are an initiative of the IUCN Species

[4] *https://www.mpabioclimate.org/*.
[5] *https://farallones.noaa.gov/*.

Survival Commission and Notarbartolo di Sciara provided a presentation about them. They are a place-based conservation tool with the potential to be delineated and managed for conservation. IMMAs are not MPAs and are not identified based on management considerations. The identification of IMMAs is an evidence-driven, purely biocentric process based on the application of scientific criteria and the best available science. There are four main IMMA criteria (species or population vulnerability; distribution and abundance; key life cycle areas; and special attributes), which include subcriteria. IMMAs are identified on a regional basis. Between 2016 and 2021, the process has concerned seven marine regions, covering about 35% of the world's ocean, resulting in the identification of 173 IMMAs. Workshops organised in each region follow a predefined process, developed in consultation with the regional marine mammal science and conservation community, to identify candidate IMMAs (cIMMAs) based on received proposals for preliminary Areas of Interest. After the workshop, cIMMAs are submitted to an Independent Review Panel, to verify that the criteria were applied correctly and that cIMMAs were identified based on robust scientific information. cIMMAs are then converted into IMMAs and are made available online via the Task Force's website and dedicated e-Atlas[6].

Place-based conservation approaches can help marine mammals cope with climate disruption by avoiding or mitigating noxious human-made pressures of a different nature that might cumulate with climate-derived pressures in their prime habitat. By pointing to marine mammal habitat whereabouts, IMMAs can indicate the need for establishing protected areas or for considering marine mammal conservation in marine spatial planning. However, climate-driven changes, in turn, affect where IMMAs are, by requiring: (a) adaptation of their boundaries as species shift their ranges poleward; and (b) reassessment of the importance of the area in terms of area occupation and the area's continued ecosystem services to the marine mammals. Accordingly, a need is recognised for repeating the region-based identification effort by reassessing IMMAs on a decadal basis.

One of the strengths of IMMAs is that all the information is gathered in one place and the workshop suggested that part of the assessment could include considering how animals might move with climate change. It was noted that IMMAs are regularly reviewed but highlighting ones which were more likely to be affected for more regular reviewing would be useful.

It was noted in discussion that a very useful aspect of the IMMA process is the collation of information on marine mammals within each area. The workshop made the following recommendation on the assessment process.

Attn: SC, R
The workshop **recommended** *that the IUCN IMMA assessment process should include an evaluation of how the habitat within the IMMA might be altered as a result of climate change and the potential for marine mammals to move to other areas in response to such changes.*

10.2 CCAMLR

Cavanagh on behalf of colleagues from the British Antarctic Survey presented on the impacts of climate change on Southern Ocean ecosystems, looking in particular at synergies between the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and IWC. Southern Ocean marine ecosystems are highly vulnerable to climate-driven change, the impacts of which must be considered as part of conservation and management. CCAMLR is aware of the urgent need to develop climate-responsive options within its ecosystem approach to management. This has been influenced by the body of research undertaken in this area by national and international programmes (including the Integrating Climate and Ecosystem Dynamics in the Southern Ocean programme - ICED; the Southern Ocean Observing System - SOOS and the Scientific Committee on Antarctic Research - SCAR). Moreover, much of this research has contributed to IPCC reports, including the Special Report on Oceans and Cryosphere in a Changing Climate (SROCC) and AR6.

While the regulation of whaling and management of whale stocks is beyond the competency of CCAMLR, the significance of whales as key components of the Antarctic marine ecosystem is increasingly important to CCAMLR in its fishery management approaches, as well as its responsibility for all marine living resources. Key aspects include whales as krill-dependent predators (density patterns, krill consumption estimates, recovery of historically exploited populations); the role of whales in biogeochemical cycling and carbon sequestration; and depredation from longlines by toothed whales (killer whales, sperm whales).

CCAMLR's Article XXIII highlights that its Scientific Committee should seek to develop co-operative working relationships and enter into agreements with the IWC. Over time the Scientific Committees of IWC and CCAMLR have developed such a relationship, including convening a joint IWC-CCAMLR workshop (CCAMLR, 2009), and further intention to hold a second one in the future.

Issues of common interest include interactions between whales and krill; ecosystem modelling; mitigation of anthropogenic threats (e.g. pollution, incidental mortality in fisheries, ship strikes), and impacts of climate change. There are clear benefits to IWC and CCAMLR of working together on climate change issues, including avoiding duplication of effort

[6]*www.marinemammalhabitat.org/imma-eatlas.*

(e.g. sharing relevant climate change information, e.g. see Cavanagh *et al.* (2021); applying relevant scientific expertise (e.g. neither body has climate experts, importance of engaging with external experts, expansion of relevant expert scientific networks); developing shared protocols and methods (e.g. common analytical tools, modelling approaches); strategic planning (e.g. helping define priorities); strengthening key messages using shared outputs (e.g. importance of coordinated long-term datasets and observational networks to better understand climate change impacts). Potential ways to facilitate further collaboration range from the individual expert level to organisational commitments (Castro Jiménez, 2019) such as a memorandum of understanding between IWC and CCAMLR.

There were discussions on the existing links between IWC and CCAMLR and earlier recommendation made by the Scientific Committee for the two organisations to work together on ecosystem function was recalled. A recent project (Castro Jiménez, 2019) explored issues of common interest between the two bodies, concluding that strengthening the relationship between CCAMLR and the IWC would be of mutual interest in addressing these. The two Secretariats have initiated discussion of next steps (including an MoU), although COVID restrictions have slowed progress. The workshop encouraged continued collaboration with CCAMLR and other Antarctic science bodies.

Attn: SC, S

The workshop recalled the Commission's desire for the IWC to continue collaboration with CCAMLR through the Scientific Committee (CO1828) and the Scientific Committee's previous recommendation on international collaboration (SC0918). It noted that climate change was an important issue for both organisations with obvious synergies. Therefore, the workshop **encouraged** *stronger collaboration between IWC and CCAMLR, as well potentially with other Antarctic science bodies (including SCAR and ICED) to enhance understanding of the impacts of climate change in Southern Ocean ecosystems, and to improve dialogue on other cross-cutting issues such as pollution, shipping and tourism.*

11. REVIEW OF ALL RECOMMENDATIONS, INCLUDING CONSIDERATION OF TARGET AUDIENCES

Due to the virtual nature of this workshop not all elements of the planned agenda had been completed. The workshop therefore made the following recommendation to address this matter.

Attn: SC

It was noted that the workshop has not completed all elements of its planned agenda. The workshop **recommended** *that a further (i.e. part two) and preferably in-person workshop, to look more fully at some matters, should be held after the review of this workshop report by the Scientific Committee.*

The workshop noted that there may be a need for new approaches to monitoring to provide the necessary data to understand and respond to climate driven changes in an appropriately rapid time frame. Table 1 identifies a number of considerations related to climate change that could be taken into account at the design stage of monitoring programmes in order to maximise the potential value of the data for understanding impacts of climate change and implementing effective management actions. However, these are broad general principles that would require further elaboration to be of most value. The workshop therefore made the following recommendation towards the appointment of a Climate Change Coordinator.

Attn: SC, CC, S

The Workshop therefore **recommended** *that the IWC seek funding to appoint a Climate Change Coordinator to generate a set of guidelines, standards and protocols for maximising the global utility of cetacean monitoring programmes and risk assessments from anthropogenic threats with respect to understanding the implications of climate change. This work would facilitate coordinated design of monitoring programmes as well as ensuring comparability in data sets for analysis.*

The initial task would be to prepare a document for the 2023 SC meeting possibly including a review of SC reports from 68A onwards and produce a summary in time for IWC69 of all the SC work relevant to climate change.

Climate-driven impacts are causing rapid changes to cetacean populations and habitats. In recognition of this fact and the options available for action from the cetacean research community, there was discussion of the need to adjust management goals from ensuring sustainability to building resilience for cetacean species in the coming decades. This approach would require scientific understanding of how climate change is impacting populations and species, marine ecosystems, and the landscape of other anthropogenic threats. In doing so, research could help identify high-priority issues, regions, or species in order to create strategic and targeted management actions that are most likely to minimize additional stressors and increase cetacean population resilience to the impacts of global change. To address these issues two tables related to research recommendations were developed (Tables 1 and 2).

Tables 1 and 2 were used to help produce overarching recommendations from the workshop:

Table 1

Issues related to climate-related research and proposed ways to address them.

Concepts	Types of impact	Issues identified at the workshop	Ideas for further research effort - see recommendations
- How climate change affects cetacean populations and species.	- Distribution, phenology, population dynamics, reproductive success, resilience, diet, health, behaviour in response to climate-induced alterations (e.g. habitat degradation, shifts in range and access to prey, exposure to novel pathogens, novel species compositions/interactions, potential trophic mismatches, and, shifts in range and access to prey).	- Need long time series to capture multiple cycles of global climate signals and/or provide baselines for cetacean responses. - Often difficult to distinguish inter-annual variability from longer-term climate-driven trends. - Confounding effects of other drivers (e.g. other anthropogenic impacts). - Climate impacts can be regionally variable or population/species-specific.	- Prioritise regions known to be experiencing intense climate change impacts, particularly those which are key habitats for cetaceans (for example, IUCN-defined IMMAs). - Improve methods to utilise results from detailed small-scale studies to make wider inferences, for example developing best practice guidance for studies, and power analysis for detection of significant effects. - Conduct multi-way analyses to identify most significant vulnerabilities for species/populations - Maximise survey effort through additional partnerships within and outside the cetacean research community to co-monitor species and relevant environmental parameters. - Assess cetacean population dynamics, behavioural responses, fertility, health, etc. following climate change-induced extreme events (e.g. marine heatwaves) to learn about cetaceans' capacity to respond to and resilience in face of extreme changes/potential future new-normal states. - Model climate impacts on cetacean habitat, prey, and populations.
- How climate change impacts marine ecosystems: using cetaceans as sentinel species. - Marine mammals can sometimes provide insights into changes within marine ecosystems where other methods fail.	- Climate-related shifts in cetacean distribution, health, diet, stranding rates, reproduction and human interactions as proxy for broader ecosystem changes. - Climate-related shifts in prey, foodweb, inter-species interactions, and in ecosystem services provided by cetaceans.	- Challenge in making marine mammal data useful to other research fields and conservation bodies. - Importance of long-term studies. - Understanding what cetaceans are indicating in relation to changes within the marine ecosystem.	- Incorporate multi-disciplinary considerations at the study design stage and identify collaborations with other environmental sciences (e.g. deep-sea, climate, cryosphere). - Investigate ways that cetaceans' 'indicator' or 'umbrella' status can be used to trigger management action. - Review and propose approaches to distinguish climate-related impacts on ecosystems from other variables. - Conduct retrospective studies of links between climate-driven changes and cetacean responses, to better interpret current and future changes.
- How climate change impacts the distribution and intensity of **other threats** to cetaceans.	- Changes in fisheries interactions, shipping routes, pollution, offshore development, noise, tourism, connected to climate (e.g. increasing marine access due to warming, oceanographic shifts in pollutant distribution). - How these stressors can combine to impact a species/population's climate resilience.	- Need for international cooperation to address transboundary/trans-nation threats (e.g. Arctic Council's Protection of Arctic Marine Environment PAME Working Group). - These 'other' threats may have more immediate impacts on cetaceans and may be more actionable for managers.	- Research needed to inform management for resilience: identify high impact or priority stressors/regions/ vulnerability windows and at-risk populations/species. - Use work on cumulative effects of multiple stressors to make inferences about climate change impacts.
- Re-assessments of **management measures** in light of climate change.	- Climate change is accelerating and intensifying population changes and management measures to mitigate threats are not keeping apace.	- How do we make management and conservation actions more dynamic and responsive to rapid climate-induced impacts or changes. - Multitude of assessment metrics available.	- Compare conservation/management outcomes across populations to contextualize and prioritize management actions. - Scientifically assess success of past management actions (e.g. positive population level responses such as increases in population size, reproductive success or improvements in health parameters) to establish best conservation practice. - Develop methods for tracking policy implementation. - Cooperate with/be aware of regional management bodies, international agreements in this regard.

Table 2

Tools and methods to assess climate-driven impacts on cetaceans.

Climate impact	Scale	Monitoring types (scale of monitoring)
Distribution/ phenology	Population/species	- Opportunistic sighting reports (population/species). - Direct survey (population level). - Passive acoustics (population level). - Satellite tracking (individual/population). - Modelling of environmental parameters and cetacean (or prey) population dynamics and distributions to inform survey locations.
Population dynamics (reproductive rates, mortality)	Population	- Direct survey in breeding areas with photo-ID. - Genetics to identify individuals/parentage (individual/population). - Hormones to assess pregnancy/stress (individual/population). - Sightings/observations e.g. cow-calf counts (population). - stranding monitoring (population).
Diet	Individual/population	- Tissue samples for stable isotopes/fatty acids (individual/population). - Faecal samples to identify prey, stomach contents of strandings (individual/population). - Prey associations based on observation/concurrent prey surveys (population). - Short-term tagging to measure foraging behaviour (individual/population). - Short-term camera-tagging/video analyses (individual).
Health	Individual/population	- Body condition via: UAV or side-on photography. - Use of noninvasive Blow collection - free-ranging cetaceans - evolving technique - various explorations (hormone, disease possible). - Tissue samples - adipose index, pollutant load (individual/population). - Novel tools epigenetics - biological age versus chronological age - concept is accelerated ageing is driven by poor health (link to IWC cumulative stressor workshop). - Use of molecular diagnostics for CDOC (cetacean diseases of concern) - the latter are likely being introduced through range expansions. - Strandings thorough workup link to IWC Stranding Expert Panel work.
Stress and behavioural responses	Individual/population	- Observational studies (e.g. changes in time spent foraging; alterations to diving/surfacing patterns; altered vocalizations/communication; avoidance behaviour; tagging studies).

Attn: R, SC

The workshop **recommended** *that work on how climate change affects cetacean populations and species should:*

(1) *prioritise regions known to be experiencing intense climate change impacts, particularly those which are key habitats for cetaceans (for example, where these may overlap with IUCN-defined IMMAs);*

(2) *improve methods to utilise results from detailed small-scale studies to make wider inferences, for example developing best practice guidance for studies, and power analysis for detection of significant effects;*

(3) *conduct multi-way analyses to identify most significant vulnerabilities for species/populations; and*

(4) *maximise survey effort through additional partnerships within and outside the cetacean research community to co-monitor species and relevant environmental parameters.*

Attn: CG, C, S, R

The workshop noted how cetaceans could be used as sentinel species providing insights into marine ecosystem changes where other methods fail. In this regard the workshop **recommended***:*

(1) *the incorporation of multi-disciplinary considerations at the design stage of any research programme and identify possible collaborations with other environmental sciences (e.g. deep-sea, climate, cryosphere);*

(2) *investigation into ways that cetaceans' 'indicator' or 'umbrella' status can be used to trigger management actions; and*

(3) *that research programmes review and propose approaches to distinguish climate-related impacts on ecosystems from other variables and conduct retrospective studies of links between climate-driven changes and cetacean responses, to better interpret current and future changes.*

Attn: CG, C, S, R

Climate change is known to impact the distribution and intensity of other threats to cetacean populations and thus the workshop **recommended** *that:*

(1) *research is needed to inform a switch in the focus for management of cetaceans from sustainability to one of building resilience in their populations;*

(2) *research is needed to identify priorities, including: high impact stressors, regions under the greatest threat, vulnerability windows and at-risk populations or species; and*
(3) *work on cumulative effects of multiple stressors should be used to make inferences about climate change impacts.*

Attn: CG, C, S, R
The workshop noted that climate change is accelerating changes in cetacean populations and current management measures to mitigate threats may no longer be suitable. The workshop therefore **recommended***:*

(1) *research to compare across populations to contextualize and prioritize management actions;*
(2) *scientific assessment of the success of past management actions to establish best conservation practice;*
(3) *the development of methods for tracking policy implementation; and*
(4) *cooperation with regional management bodies and international agreements in the mitigation of climate threats to cetacean populations.*

12. CLOSE OF MEETING AND FUTURE PLANS

Staniland, on behalf of Zerbini the Chair of the SC and Lent the Executive secretary thanked everyone for participating in the workshop, for sharing their expertise and giving their valuable time. He noted that all the speakers had made excellent presentations and the workshop had hosted some fascinating discussions.

He thanked the rapporteurs and gave special thanks to Simmonds for organising the workshop that had presented a number of challenges notably an enforced shift from being held in person to virtual. Staniland noted the amazing job Simmonds had done facilitating the workshop discussions and encouraging people to produce text, tables and recommendations.

The Chair thanked everyone for taking part and noted that we had heard not only about whales but also 'diatom fluff', 'black swans' and many other things, and that he had learnt a lot. He recognised the difficulties and frustration of working across many time zones in the virtual world and thanked everyone for their patience. He thanked the IWC team for their support, including Julie Creek and the IT staff. He also thanked Russell Leaper, Iain Staniland, Laetitia Nunny and Silvia Frey for invaluable support in the preparation and delivery of the workshop and, likewise, the workshop Steering Committee. Finally, he closed the meeting by wishing everyone a happy, safe and healthy festive season.

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Annex A

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Annex B

Agenda

1. Introductions
2. Review of TOR and agenda
3. Appointment of Chair and Rapporteurs
4. Previous and ongoing work on climate change undertaken by IWC
5. Summary of IPCC latest report (executive summary)
6. Review of the latest developments in terms of understanding the implications for cetaceans of climate change
   (a) Major climate and non-climate drivers for cetaceans impacts, including synergies
   (b) Predicted effects (cetaceans, habitats and prey)
   Direct and indirect impacts
   (c) Observed effects (cetaceans, habitats and prey and other species)
   Direct and indirect impacts
   Other species - pinniped examples
   (d) Case studies
   - North Atlantic right whales
   - Gray whale die off
   - Southern right whale recovery affected by El Niño
   - Movement of whale species - e.g. into Arctic
   - Out of habitat animals - e.g. wandering belugas
   - Baltic porpoises
   - River dolphins

   (e) Detecting effects
   i. Population counts
   ii. Health assessments
   Nutritional assessments (and fecundity), biopsies, photography
   Indicators needed to assess status of cetaceans
   iii. Migration and habitat selection
   iv. Consideration of how to better survey cetacean population that may move habitats
7. Report from the IWC Ecosystems Functioning Workshop (summary and highlighting any issues of mutual interest)
8. Can cetaceans be used as indicators of climate change?
   (a) Which species/where/what and indicator for what?
   (b) How do we tease out the effects of climate change from other factors
   (c) Linking this to appropriate political processes - e.g. in other conventions such as the potential for cetacean indicators to feed into CBD - monitoring framework and providing examples of cetaceans into the work of the IPCC
   (d) Identifying and collaborating with relevant climate processes and initiatives
9. Responding to the climate change threat through 'climate SMART' management or similar approaches
   (a) Direct response to address and reduce causes of Climate Change - including how to make whale assessments carbon neutral
   (b) Adaptive management 1: Potential management actions in response to climate driven changes that may make cetaceans more vulnerable to anthropogenic threats (e.g. changes in distribution in relation to shipping and fisheries, impacts on health)
   (c) Adaptive management 2: Responses to expected and observed changes in human activities as a result of climate driven changes (e.g. increased shipping in Arctic, changes in fisheries, storm related sewage discharges) and potential management actions in anticipation of these changes
   Slowing shipping/blue carbon

(d) Adaptation Tool Box: Management to enhance the adaptability and resilience of cetacean species
- Climate Smart Conservation Cycle
- Climate informed goals and objectives
- Vulnerability assessments (examples: NOAA and ECOADAPT)
- Scenario planning
- RAD (Resist, Adapt, Direct)
- The role of MPAs/blue carbon

(e) Issues with implementing management
(f) Limitations in our current assessment capacity and data gaps
(g) Policy issues
(h) The use of vulnerability assessment(s)
(i) Other responses?

10. Recommendations for further research and improving policy, including recommendations to other IGOs and building liaison, including IUCN and IMMAs
11. Review of all recommendations, including consideration of target audiences

Annex C

Previous Recommendations

2010 RECOMMENDATIONS MADE BY THE WORKSHOP ON SMALL CETACEANS AND CLIMATE CHANGE

Held Vienna, Austria from 28 November to 1 December 2010. 2011 SC Report, endorsed at IWC63.

Number	Text	Progress
SC1001	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 recognised 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.	Ask
SC1002	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.	Complete
SC1004	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.	Integrated into other work areas (E)
SC1006	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.	Integrated into other work areas (E)
SC1011	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).	Superseded Integrated into other work areas (E)
SC1015	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.	Check with ASCOBANS if this area has been investigated A major review on CC in the Baltic is in press and does consider the one cetaceans species there. See pre-print here: *https://esd.copernicus.org/preprints/esd-2021-67/* One of the authors will be invited to the w/s.
SC1018	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.	Check in for latest info with Canary Islands, possibly CCAMLR, also integrated into other work areas
SC1021	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	Ongoing, incorporated into other work areas
SC1024	The Workshop recommended that a comprehensive assessment be conducted on the implications of climate change on freshwater-dependent cetaceans.	Ask Fernando *et al.*
SC1025	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.	Ask WW Sub-com
SC1028	The Workshop 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.	Ongoing incorporated in other work
SC1030	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.	OPEN - discuss

Number	Text	Progress
SC1031	With respect to freshwater cetacean conservation, the 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.	No direct actions
SC1033	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.	Complete
SC1037	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.	Superseded

2014 IWC WORKSHOP ON IMPACTS OF INCREASED MARINE ACTIVITIES ON CETACEANS IN THE ARCTIC

Held 6-7 March 2014, Anchorage, Alaska, USA. The workshop focused on human activities related to oil and gas exploration, commercial shipping and tourism, as well as likely changes to the ecosystem as a result of climate change. Endorsed at IWC65. (CO1429).

Number	Text	Comment
SC1401	The Workshop strongly emphasized that the IWC has an important role to play in the protection of the Arctic environment and its subsistence whaling communities. An important challenge for the IWC is to determine the details of how best it can encourage and contribute to such a major effort in a timely and comprehensive manner.	
SC1402	The Workshop also recommends that the IWC considers including a standing agenda item on the Arctic at each biennial meeting to consolidate the progress made by its subsidiary bodies and the Secretariat during intersessional periods and to discuss future actions.	
SC1403	The Workshop recognises the importance of the work already underway by the Arctic Council and its working groups and programmes (see Item 5.1.1). As a matter of highest priority, it strongly recommends that the IWC Secretariat: (1) Approaches the Arctic Council requesting observer status and provides as part of that request a short summary of the types of expertise the IWC can provide (see Item 5.1.4) as well as a copy of the present report; (2) Liaises with the Arctic Council Secretariat and chairs of the various Arctic Council working groups to determine how best the IWC can contribute to and participate in their work, including cetacean-related aspects of the development of common standards, measures and monitoring across the Arctic (see Item 5.1.3); (3) Invites the Arctic Council to participate in relevant IWC meetings and workshops, including those of Committees, sub-committees and working groups; (4) Liaises with the Arctic Council over the need for a formal Memorandum of Understanding between the two bodies, as appropriate; (5) Invites the Arctic Council to publicise the IWC global ship strikes database and encourage member nations, observer nations and observers to submit data to the database to allow a better characterisation of the issue for the Arctic; (6) Encourages the Arctic Council to continue to recognise the importance of taking into account the needs of subsistence whaling communities and offers to provide information on IWC regulated hunts.	
SC1404	The Workshop requests that the Commission develops an approach to funding IWC participation at relevant meetings of the Arctic Council and its working groups.	
SC1405	The Workshop recommends increased co-operation by the IWC (Secretariat and member nations) with IMO with respect to mitigation measures for threats to cetaceans (e.g. Traffic Separation Schemes, speed restrictions, noise reduction) and increased awareness of the issue of ship strikes and the importance of the IWC global ship strikes database. It strongly urges Arctic nations to submit data to the IWC database to allow priorities for action to be developed and referred to the July 2014 IWC workshop on ship strikes as an appropriate place to take this general issue forward.	
SC1406	The Workshop strongly endorses the need for such a code [mandatory international code of safety for ships operating in polar waters (the 'Polar Code')] and commends the excellent work carried out to date. It urges IWC member nations and others to support the finalisation and ratification of the Polar Code as soon as possible.	
SC1408	In an IWC context, the Workshop recommends: (1) Stakeholder participation is encouraged in relevant meetings of the IWC and its subsidiary bodies, as well as meetings of other intergovernmental organisations such as the Arctic Council and national authorities.	

Number	Text	Comment
SC1409	In an IWC context, the Workshop recommends: (2) The IWC Secretariat, in consultation with others (e.g. the Arctic Council and IMO secretariats), draws up a list of relevant international and national stakeholder bodies for the Arctic region, in light of the discussions at this workshop that prioritised the following: oil and gas operations; vessel traffic (of many kinds including transport, tourism/whale watching, fishing, servicing oil and gas operations); fishing activities; and hunting. (3) The IWC Secretariat contacts the identified organisations with a copy of the present Workshop report and subsequent Commission discussions of it, expressing the interest of the IWC in co-operating and providing advice on issues of mutual interest including: (1) the sharing of scientific expertise (see Item 5.1.4); (2) assistance with issues of data sharing and common field work and analyses; and (3) information on subsistence hunts.	
SC1410	In an IWC context, the Workshop recommends: (4) The IWC considers additional ways (including possible expansion of the Commission's successful whale disentanglement training effort) to increase the awareness of and sensitivity of industry operators (e.g. the shipping, oil and gas, fishing and tourism sectors) to conservation concerns and the cultural aspects of aboriginal subsistence whaling. (5) The IWC considers mechanisms to provide technical support to individual companies or industry bodies.	
SC1411	The Workshop recommends that the IWC Scientific Committee be requested to: (1) Develop a summary of present knowledge of cetacean population status, distribution and movements, density and important habitat of the Arctic species; (2) Develop plans for a co-hosted specialist workshop or workshops with appropriate stakeholder participation (with a focus on the Arctic and with particular case studies to be determined) on identifying and evaluating threats to cetaceans from human activities including: (a) Data and analytical requirements (both for cetaceans and human activities) for identifying high risk areas to cetaceans at the correct geographical and temporal scales; (b) Evaluation of non-direct threats to cetaceans at the population level including chemical pollution, noise, climate change etc.; (c) Methods to examine synergistic and cumulative effects of a range of actual and potential threats at the population level (see Item 4.1.3); (d) Specific recommendations with respect to data requirements and monitoring for the Arctic region in the light of projected human activities within the region. (3) Collate a summary of advice relevant to the Arctic it has provided with respect to a number of issues identified at this workshop including: climate change; chronic and acute noise; oil spills, ship strikes, fishery bycatch, habitat degradation; and (4) work with the IWC Secretariat to increase the prominence, awareness and availability of its advice through the IWC website.	Refer to the workshop for assessment and discussion
SC1412	The Workshop also recommends that the IWC Scientific Committee contributes to efforts to develop of common standards, measures and monitoring across the Arctic (see Item 5.1.3) with respect to issues related to the effects of human activities on cetaceans.	

2009 RESOLUTIONS ENDORSED AT IWC63 BY CONSENSUS

Number	Text
CO0902	Resolution 2009-1 ENDORSES the outcome of the climate change workshop and associated recommendations of the Scientific Committee given in IWC/61/Rep1, including the need to expand the current international multi-disciplinary efforts and collaborative work with other relevant bodies;
CO0903	Resolution 2009-1 REQUESTS Contracting Governments to incorporate climate change considerations into existing conservation and management plans
CO0904	Resolution 2009-1 DIRECTS the Scientific Committee to continue its work on studies of climate change and the impacts of other environmental changes on cetaceans, as appropriate
CO0907	Resolution 2009-1 APPEALS to all Contracting Governments to take urgent action to reduce the rate and extent of climate change.

2011 RECOMMENDATIONS MADE BY THE SC ENDORSED AT IWC63

Number	Text	Comments
SC1101	The Committee endorses the Workshop's recommendations, many of which were in accord with previous Committee recommendations on the general subject of the impact of climate change on cetaceans (e.g. IWC, 2010j).	Referring to the small cetaceans and climate change workshop

2018 RESOLUTION ENDORSED AT IWC67 BY VOTE

Number	Text
CO1804	Resolution 2018-2 Encourages Contracting Governments to integrate the value of cetaceans' ecological roles into local, regional and global organisations on biodiversity and environment, including climate change and conservation policies.

2015 WORK PLAN MADE BY THE SC ENDORSED AT IWC66

Number	Text	
SC1626	The Committee agrees to continue the intersessional working group under Simmonds (see Annex V for members and terms of reference) to develop a strategy to address the potential vulnerability of climate change on cetacean species.	Ongoing

2017 RECOMMENDATION AND WORK PLAN MADE BY THE SC ENDORSED AT IWC67

Number	Text	Progress
SC17352	With respect to climate change, the Committee agrees that: (1) the impact of climate change should be considered in an integrated manner highlighted when it is a specific driver within the topics being covered; and (2) that the intersessional correspondence group (Annex X) refine ideas for a future workshop and identify relevant climate change issues, noting the discussions under Item 15.10.1.	In progress (this workshop 2021)
SC17353	The Committee agrees that the thematic and focus topics of the Standing Working Group on Environmental Concerns are all occurring in the context of climate change, as are all other topics considered in several subcommittees of the Committee (e.g. SM, EM). Therefore, the Standing Working Group on Environmental Concerns recommends that Climate Change be better integrated in the work of the full Committee. The Committee agrees that Arctic Issues will no longer be a standing topic in the Standing Working Group on Environmental Concerns agenda and papers would be addressed under the most appropriate agenda items for the issue being presented.	Consider within this workshop, likely to be superseded for a stand alone climate change group

2018 SC DRAWS ATTENTION TO ENDORSED AT IWC67

Number	Text
SC1891	The Committee draws attention to the fact that climate change remains a threat that interacts with other threats and stressors impacting cetacean populations.

2021 SC RECOMMENDATION AND WORK PLAN PENDING ENDORSEMENT

Number	Text	Progress
SC21132	The Committee reiterates the importance of understanding baleen whale demographics and long-term environmental variability and re-established an intersessional corresponding group led by Cooke (convenor) with membership of Butterworth, Friedlaender, Kitakado, de la Mare, Palacios and Tulloch to conduct a literature review into the effects of climate change and environmental variability on whales and marine ecosystems.	Check in with Cooke on this
SC2143	The Committee encourages: (1) that research include continuous and simultaneous passive acoustic monitoring in identified ASHW habitat in both the western Arabian Sea (different parts of Oman's waters) and eastern Arabian Sea (Pakistan, India and Sri Lanka) to better understand the population's spatiotemporal distribution and potential connectivity across a larger area of suspected range, as well as to understand if range or distribution shifts begin to emerge as a result of climate change and other threats (noting that this technique also yields valuable data on other whale species, e.g. blue whales); (2) that research include the use of UAVs to assess body condition, and that body condition indices be used together with other metrics to assess seasonal and annual variation and to evaluate health, scarring, and foraging success (e.g. Ramp *et al.* 2021); and (3) that future research include methods to assess (modelled) whale distribution in relation to oceanographic variables and data on fisheries and likely prey species, to better understand the drivers of distribution for ASHW, as well as the potential threat of fisheries interactions.	Check in with Tim and/or Gianna for this

Annex D

List of Recent Relevant Literature

Alava, J.J., Cisneros-Montemayor, A.M., Sumaila, U.R., *et al.* 2018. Projected amplification of food web bioaccumulation of MeHg and PCBs under climate change in the Northeastern Pacific. *Scientific Reports* 8, 13460. *https://doi.org/10.1038/s41598-018-31824-5*

Albouy, C., Delattre, V., Donati, G., *et al.* 2020. Global vulnerability of marine mammals to global warming. *Scientific Reports* 10, 548. *https://doi.org/10.1038/s41598-019-57280-3*

Alvarado-Rybak, M., Toro, F., Escobar-Dodero, J., *et al.* 2020. 50 Years of Cetacean Strandings Reveal a Concerning Rise in Chilean Patagonia. *Scientific Reports* 10, 9511. *https://doi.org/10.1038/s41598-020-66484-x*

Amstrup, S.C. and Lehner, F. 2017. Anthropogenic Ocean Change: The Consummate Threat to Marine Mammal Welfare, in: A. Butterworth (Ed.) *Marine Mammal Welfare*. Springer, Cham, Switzerland, pp. 9-26.

Askin, N., Belanger, M. and Wittlich, C. 2017. Humpback whale expansion and climate change - evidence of foraging in new habitats. *Journal of Marine Animals and their Ecology* 9(1), 13-17.

Becker, E.A., Forney, K.A., Redfern, J.V., *et al.* 2019. Predicting cetacean abundance and distribution in a changing climate. *Diversity and Distributions* 25, 626-643. *https://doi.org/10.1111/ddi.12867*

Berger, J., Hartway, C., Gruzdev, A. *et al.* 2018. Climate Degradation and Extreme Icing Events Constrain Life in Cold-Adapted Mammals. *Scientific Reports* 8, 1156. *https://doi.org/10.1038/s41598-018-19416-9*

Bestley, S., Ropert-Coudert, Y., Bengtson Nash, S., *et al.* 2020. Marine Ecosystem Assessment for the Southern Ocean: Birds and Marine Mammals in a Changing Climate. *Frontiers in Ecology and Evolution*, 8, 566936. *https://doi:10.3389/fevo.2020.566936*

Boyd, C. and Punt, A.E. 2021. Shifting trends: Detecting changes in cetacean population dynamics in shifting habitat. *PLOS ONE* 16, 1-22. *https://doi.org/10.1371/journal.pone.0251522*

Brower, A.A., Clarke, J.T. and Ferguson, M.C. 2018. Increased sightings of subArctic cetaceans in the eastern Chukchi Sea, 2008-2016: population recovery, response to climate change, or increased survey effort? *Polar Biology*, 41, 1033-1039. *https://doi.org/10.1007/s00300-018-2257-x*

Brüniche-Olsen, A., Bickham, J.W., Godard-Codding, C.A., *et al.* 2021. Influence of Holocene habitat availability on Pacific gray whale (*Eschrichtius robustus*) population dynamics as inferred from whole mitochondrial genome sequences and environmental niche modeling. *Journal of Mammalogy* 102, 986-999. *https://doi.org/10.1093/jmammal/gyab032*

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